California Statewide Travel Demand Model, Version 2.0

Short Distance Personal Travel Model: Part 2 of 3

final

report

prepared for

California Department of Transportation

prepared by

Cambridge Systematics, Inc.

and

HBA Specto, Inc.

May 2014

www.camsys.com

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date

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1.0 Introduction

This technical note is Part 2 of a series of three technical notes that describe the Short Distance Personal Travel Model (SDPTM) component of the California Statewide Travel Demand Model Version 2.0 (CSTDM 2.0). The documentation is split into three parts to keep individual document and computer file size to a manageable level. Together they describe the complete model features, calibration and implementation. The original estimations of the models are mainly described in separate technical notes.

Technical Note Part 1 contains details of:

- Model Overview;
- Long-Term Decision Models:
  - Person Driving License Models;
  - Household Auto Ownership Models;
  - Person Work At Home Model;
  - Person Work Location Models;
    - "Simplified" Work Tour Mode Choice Models;
  - Person School Location Models;
    - "Simplified" School Tour Mode Choice Models;
- Calibration of Long Term Decision Models.

Technical Note Part 2 (this document) contains details of:

- Day Pattern Choice Models:
  - Day Role Choice;
  - Work Day Pattern Group Choice;
  - School Day Pattern Group Choice;
  - Other Day Pattern Group Choice.
- Main Tour Mode Models:
  - Work Tour Mode Models;
  - School Tour Mode Models;
  - "Other" Tour Mode Models.
- Calibration of Day Pattern and Main Tour Mode Models.

Technical Note Part 3 contains details of:

- Primary Destination Choice Models for "Other" Tours
- Subtour Mode Choice Models;
- Secondary Destination Choice Models;
- Trip Mode Choice Models;
- Calibration of Primary and Secondary Destination/Sub-Tour and Trip Mode Choice Models;
- Implementation in CSTDM 2.0 Model Framework.

2.0 Day Pattern Choice Models

The SDPTM day pattern model selects a day pattern for each modeled person.

In the CSTDM 2.0 an additional Long Distance Travel Choice (LDTC) sub-model has been introduced as part of the Long Distance Personal Travel Model (LDPTM) application. This LDTC model is described fully in the LDPTM documentation. It allocates each household in California to one of three categories:

- One or more members of the household are involved in a Long Distance tour (>100 miles) within the State (on the model travel day). For these households the LDPTM forecasts which household members are involved in the long distance tour. All household members NOT making long distance trips are returned to the SDPTM to have their SDPTM day pattern, and overall travel, forecast;
- One or more members of the household are involved in an Out of State trip (on the model travel day). For these households the LDPTM forecasts which household members are making out of state trips. All household members NOT making out of state trips are returned to the SDPTM to have their SDPTM day pattern, and travel, forecast;
- All household members do NOT make a Long Distance Trip or an Out of State trip (on the model travel day). For these households, all household members NOT making long distance trips are returned to the SDPTM to have their SDPTM day pattern and travel forecast.

This model enhancement thus explicitly allocates each California resident to a valid activity on the model travel day, and avoids the possibility of persons being allocated to both short and long distance travel (or neither).

A day pattern in the SDPTM is a combination of activities and the trips between them. An example day pattern (the second most common) is O2W4O, which represents a home activity (O), followed by AM peak travel (2) to a work activity (W), followed by PM peak travel (4) back to home (O). More complex day patterns can involve more complex tours, or multiple tours. The model architecture supports day patterns that do not begin at home, or that do not end at home (these are unusual, typically involving overnight activities).

The day patterns from the CSTDM combined travel surveys are used in this model. There are a total of 78,237 day patterns observed.

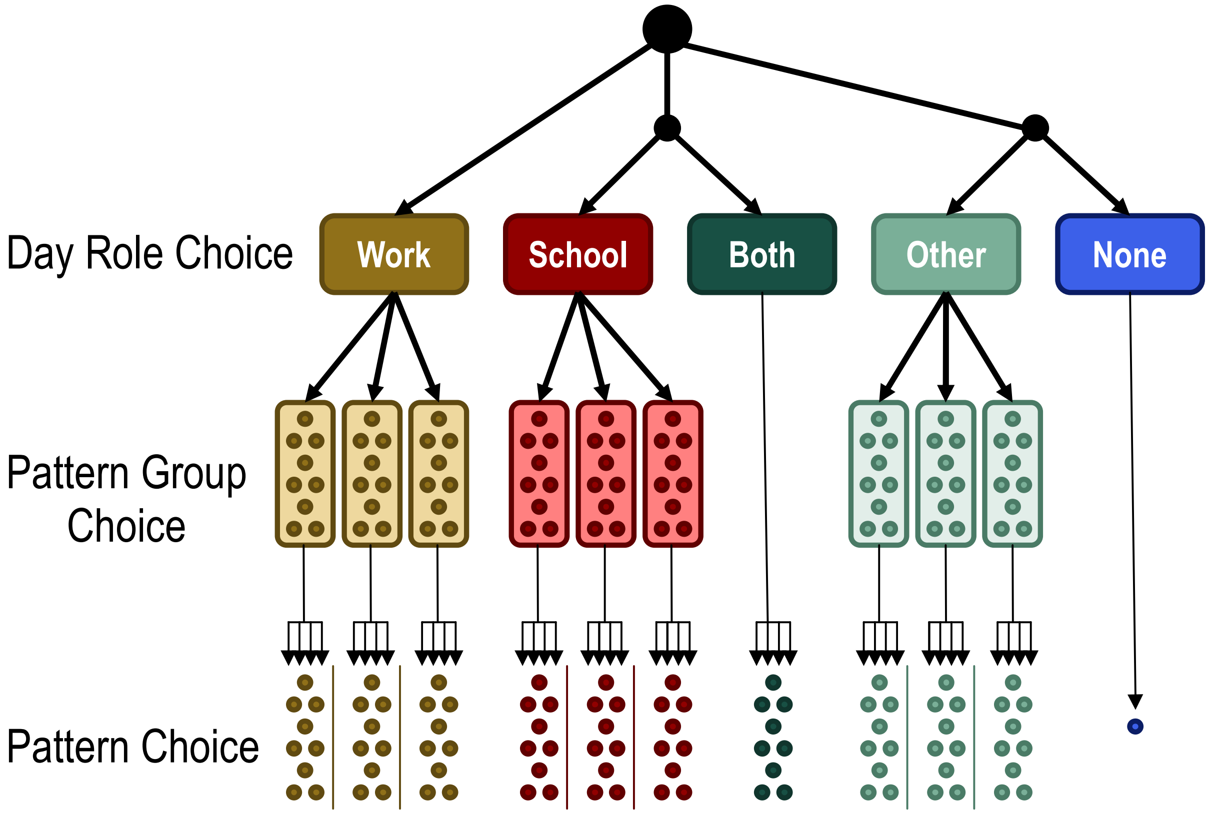
The day pattern choice model has three levels, each contingent on the results of the previous model.

- The **day role model** chooses between five "roles" based on the presence of mandatory activities in the day. The five roles are: work; school; both work and school; neither work nor school (but "other" travel); no travel at all. It is a nested logit model, considering a wide variety of socioeconomic, demographic, and accessibility factors.

- The **pattern group models** choose between groups of possible day patterns; if a person has chosen to work during the day, the possible groups of day patterns consider different general arrangements of the day; the pattern groups focus primarily on the amount of travel (number of trips and tours) and the properties of tours for the primary activity. There are three logit choice models, one for each of work, school and other days. There are relatively few observations for days with both work and school (about 1 percent of days), so the development of a pattern group level model dealing with Both day roles was not considered as necessary as the others, and the day pattern bypasses this module if Both is chosen as a day role, proceeding to pattern choice; for days with no travel, there is only one possible day pattern, to stay at home all day, so a pattern group model is redundant.
- The specific **pattern choice models** are conditional on the choice of day role and pattern group. This model chooses a specific day pattern from the possible observed patterns within a pattern group. In some cases, there is only one possible pattern to be chosen; for example, the work day with travel to work in the AM peak, return home in the PM peak and no other travel, which is a very common work day pattern, and is the only specific pattern in the group. In all cases, this model selects a specific pattern based on the observed frequency distribution of the patterns within the pattern group.

Figure 2.1 below summarizes the day pattern choice model.

Figure 2.1 Day Pattern Choice Model Structure



Many aspects of the Day Pattern Choice Model use the idea of "person types," a mutually exclusive set of seven categories that the actors in the model are classified into. These person types are:

- **Youth Other (YO).** Children under the age of 18 not attending school. These are almost entirely preschool children under the age of 6.
- **Grade School (GS).** Children attending grade school (K-12),
- **Post Secondary (PS).** Students enrolled in post-secondary educational institutions, such as colleges. Note that persons who both work and attend school are considered students.
- **Workers, Full-time (WFT).** Persons working 30 or more hours per week and not attending school full-time,
- **Workers, Part-time (WPT).** Persons working less than 30 hours per week and not attending school full-time,
- **Adult Others (AO).** Adults, aged 18 to 64, not working and not attending school (mostly homemakers, and early retirees).

- **Seniors (Sen).** Adults aged 65 plus and not working or attending school full-time. Note that people over 65 who work are classified as workers and not as seniors.

The two person types Full-time Workers and Part-time Workers are sometimes combined to represent one "Workers" group. The person types Adult Others and Seniors are sometimes combined to represent one "Non Working Adults" group, also referred to as NWA.

2.1 DAY ROLE MODEL

The Day Role model selects one of five possible day roles. Day patterns can be grouped based on the primary (often called "mandatory") activity into five categories based on the role that the person is performing in society:

- **Work**. Days with a work activity (but no school activity);
- **School**. Days with a school activity (but no work activity);
- **Both**. Days with both a work and a school activity;
- **Other**. Days with travel to out-of-home activities, but no work or school activities; and
- **None**: Days with no travel.

The observed frequencies of these day patterns are shown in Table 2.1 below.

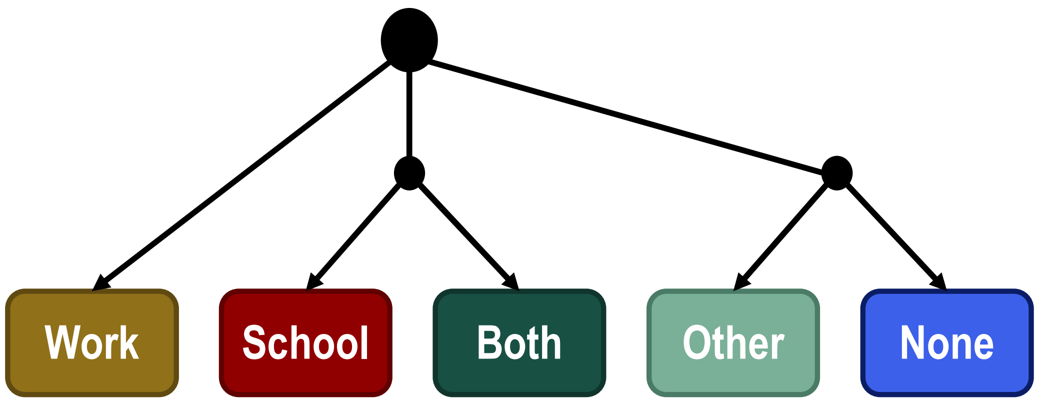
Table 2.1 Basic Day Roles

Type	Observations	Scaled Proportion
Work	29,312	33.4%
School	13,671	20.4%
Both	983	1.2%
Other	21,642	27.6%
None	12,629	17.4%

To select a day role, a nested multinomial logit choice model is used to develop probabilities for every person in the model. This model was estimated in ALOGIT using the combined statewide surveys dataset developed for the CSTDM, along with the adjustments made to these parameters from calibration. The parameters presented here are, therefore, the final ones used in the CSTDM 2.0 SDPTM.

Several nesting structures were tested; the one that performed the best was retained. The nest has Work on a separate branch, while School and Both are in one nest, and Other and None are in another. This suggests that Both (which includes both a work and a school activity) is more similar to School than it is to Work; it is more students with jobs than workers also attending school. The nesting structure is shown in Figure 2.2 below. Note that, because there are no parameters shared between alternatives, there is no need for "dummy" nodes in the ALOGIT estimation, unlike the tour mode choice models.

Figure 2.2 Day Role Choice Nesting Structure



The model parameters are given in Tables 2.2, 2.3, and 2.4 below. Income parameters are summarized in Table 2.3, which has a different structure for compactness, presenting parameters affecting the None alternative first, then parameters affecting the Work alternative.

Table 2.2 Day Role Choice Model Parameters (Person and HH Properties)

Parameter		Work	School	Both	Other	None
	Nesting coefficient	n/a	0.5612		0.8084	
Alt. Spec Constants	Alt. Specific Constant, Youth Other	-3.4574	-0.1433	-7.6958	1.1715	0
	ASC, Grade School	-1.3335	6.0587	-1.9727	3.8457	0
	ASC, Post-Secondary	-4.4805	3.0407	-1.5921	-0.5051	0
	ASC, Worker Full-time	4.5723	0.1626	-0.6304	2.8355	0
	ASC, Worker Part-time	2.3822	-1.9212	-1.6857	1.8407	0
	ASC, Adult Other	-2.6172	-7.5694	-8.8613	-0.8579	0
	ASC, Senior	-2.8751	-9.4970	-13.4504	0.4539	0
Employment	Work At Home, Full-time worker	-2.0772	0	0	0	0
	Work At Home, Part-time worker	-1.5900	0	0	0	0
	Grade School with job	3.7571	0	4.0731	0	0
	Post-Secondary with full-time job	4.5369	0	4.6052	0	0
	Post-Secondary with part-time job	3.3064	0	3.6288	0	0

Parameter		Work	School	Both	Other	None
Age	Age, Youth Other (maximum 10)	0	0.4801	0	0	0
	Age, Grade school (maximum 19)	0	0.4692	0.2422	0	0
	Age^2, Grade school (maximum 19)	0	-0.01932	0	0	0
	Age, Post-Secondary (minimum 17)	0.1133	0.02251	0	0.09700	0
	Age^2, Post-Secondary (minimum 17)	-0.00110	-0.01913	0	-0.00085	0
	Age, Adult Other (minimum 17)	0	0	0	0	-0.07999
	Age^2, Adult Other (minimum 17)	0	0	0	0	0.00089
	Age, Senior (years over 75)	0	0	0	0	0.04343
	Age^2, Senior (years over 75)	0	0	0	0	0.00316
HH Size/Makeup	Post-Secondary living alone	0	0	0	0	-0.3306
	Single parent (only person 16+, 1+ <=16)	0	0	0	0	-0.6886
	Senior, HH has worker	0	0	0	0	0.5333
	Senior living alone	0	0	0	0	0.2932
	Senior, 3+ person HH	0	0	0	0	0.5177
Children w/NWA	HH has NWA, Youth aged 0-2	0	0	0	0.9656	0.9684
	HH has NWA, Youth aged 3+	0	0	0	1.6115	1.8588
	HH has NWA, Grade School age <10	0	0	0	0.3628	0.6198
	HH has NWA, Grade School age 10-13	0	0	0	0.4491	1.0217
	HH has NWA, Grade School age 14+	0	0	0	0.2897	0.7866
Adults with Children (Ages 0-15)	Adult Other, 1 child age <3	0	0	0	0	0.2257
	Adult Other, 1 child age 3-5	0	0	0	0.4890	0
	Adult Other, 2+ children, youngest <3	0	0	0	0	0.1852
	Adult Other, 2+ children, youngest 3-5	0	0	0	0.8537	0
	Adult Other, 2+ children, all aged 6-15	0	0	0	0.2106	0
	Worker, Female, 1 child age <3	0	0	0	0.9313	0.8583
	Worker, Female, 1 child age 3-5	0	0	0	0.2357	0
	Worker, Female, 1 child age 6-15	0	0	0	0.2357	0
	Worker, Female, 2+ children, youngest <3	0	0	0	0.7958	1.2147
	Worker, Fem., 2+ children, all aged 3-15	0	0	0	0.6147	0
	Worker, Part-time, 2+ children (under 16)	0	0	0	0	-0.5779

<table>
<tr><th colspan="2">Parameter</th><th>Work</th><th>School</th><th>Both</th><th>Other</th><th>None</th></tr>
<tr><td rowspan="7">Industry and Occupation</td><td>Worker, Leisure and Hospitality Industry</td><td>-0.2289</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Education and Health Industry</td><td>0.0891</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Primary and Secondary Industry</td><td>0.1435</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Sales, Food & Ent. occupation</td><td>-0.2161</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Service Non Sales occupation</td><td>-0.3021</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Manag./Business occupation</td><td>0.2351</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Health occupation</td><td>-0.4560</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Table 2.3 Day Role Choice Model Parameters (Income)

<table>
<tr><th></th><th><10K</th><th>10-25K</th><th>25-35K</th><th>35-50K</th><th>50-75K</th><th>75-100K</th><th>100K+</th></tr>
<tr><td colspan="8">None</td></tr>
<tr><td>0 worker HH</td><td colspan="3">-0.2583</td><td colspan="4">-0.5504</td></tr>
<tr><td>1 worker HH</td><td colspan="3">0</td><td colspan="3">-0.2040</td><td>-0.5969</td></tr>
<tr><td>2 worker HH</td><td colspan="2">0.2350</td><td colspan="4">0</td><td>-0.2041</td></tr>
<tr><td>3+ worker HH</td><td colspan="2">0.8203</td><td colspan="2">0.6128</td><td colspan="3">0.4607</td></tr>
<tr><td>Youth</td><td>0.9430</td><td>0.8245</td><td>0.7581</td><td>0.5564</td><td>0.3883</td><td>0</td><td>0</td></tr>
<tr><td>Grade School</td><td>0.8722</td><td>0.5137</td><td>0.4623</td><td>0.4482</td><td>0.3780</td><td>0</td><td>0</td></tr>
<tr><td>Senior</td><td>1.2269</td><td>0.7034</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Full-time</td><td>0.5409</td><td>0.2458</td><td>0.1500</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Worker, Part-time</td><td colspan="3">0.5081</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="8">Work</td></tr>
<tr><td>Worker Full-time</td><td>-0.5244</td><td>-0.3713</td><td colspan="2">-0.1893</td><td>-0.1517</td><td>0</td><td>0</td></tr>
</table>

Table 2.4 Day Role Choice Model Parameters (Accessibility and Auto Ownership)

Parameter		Work	School	Both	Other	None
Auto Ownership	No cars, Youth Other	0	0	0	0	1.1819
	No cars, Grade School	0	0	-0.9443	0	0.5195
	No cars, Post-Secondary	0	0	0	0	0.9857
	No cars, Worker Full-time	0	0	0	0	0.3839
	No cars, Worker Part-time	0	0	0	0	0.8175
	No cars, Adult Other	0	0	0	0	0.6200
	No cars, Senior	0	0	0	0	1.0501
	Insufficient cars, Youth Other	0	0	0	0	0.1750
	Insufficient cars, Grade School	0	0	-0.9443	0	0
	Insufficient cars, Post-Secondary	0	0	0	0	0.3294
	Insufficient cars, Adult Other	0	0	0	0	0.1432
Accessibilities	Grade School, School Location logsum	0	0.2333	0	0	0
	Worker with car, Work Location logsum	-0.2053	0	0	0	0
	Worker without car, Work Location logsum	0.1873	0	0	0	0
	Post-Secondary, Shop SOV Logsum	0	0	0	0.01896	0
	Worker, Shop SOV Logsum	0	0	0	0.01896	0
	Adult Other, <$25K Shop SOV Logsum	0	0	0	0	-0.00302
	Adult Other, $25-100K Shop SOV Logsum	0	0	0	0	-0.03511
	Adult Other, $100K+ Shop SOV Logsum	0	0	0	0	-0.04883
	Senior, <$25K Shop SOV Logsum	0	0	0	0	-0.08872
	Senior, $25K+ Shop SOV Logsum	0	0	0	0	-0.03859
	Senior, Shop WAT Logsum	0	0	0	0	-0.01566

The logsums described in Table 2.4 above are:

- **Grade School Location.** Uses Long-Term Decision logsum for grade school students aged 10 to 14, medium income, sufficient auto ownership.
- **Worker with Car Work Location.** Used for all workers in households with one or more cars. Logsum value uses Long-Term Decision Work logsum for medium-income household with sufficient cars. The parameters are multiplied by the maximum of (-2.5-logsum or 0) (i.e., this applies only to the portion of logsum less than -2.5 (and implicitly reverses sign)). This LTD Work logsum has a value of -2.5 at a distance of approximately 30 miles from home.

- **Worker without Car Work Location.** Used for workers in households without cars. Logsum value uses Long-Term Decision Work logsum for low-income household with no cars, with no additional transformations.
- **Shop SOV Logsum.** Uses the SOV logsum from the Tour Mode Choice model for a Shop tour, with both outbound and return travel in the midday.
- **Shop WAT Logsum.** Uses the WAT logsum from the Tour Mode Choice model for a Shop tour, with both outbound and return travel in the midday.

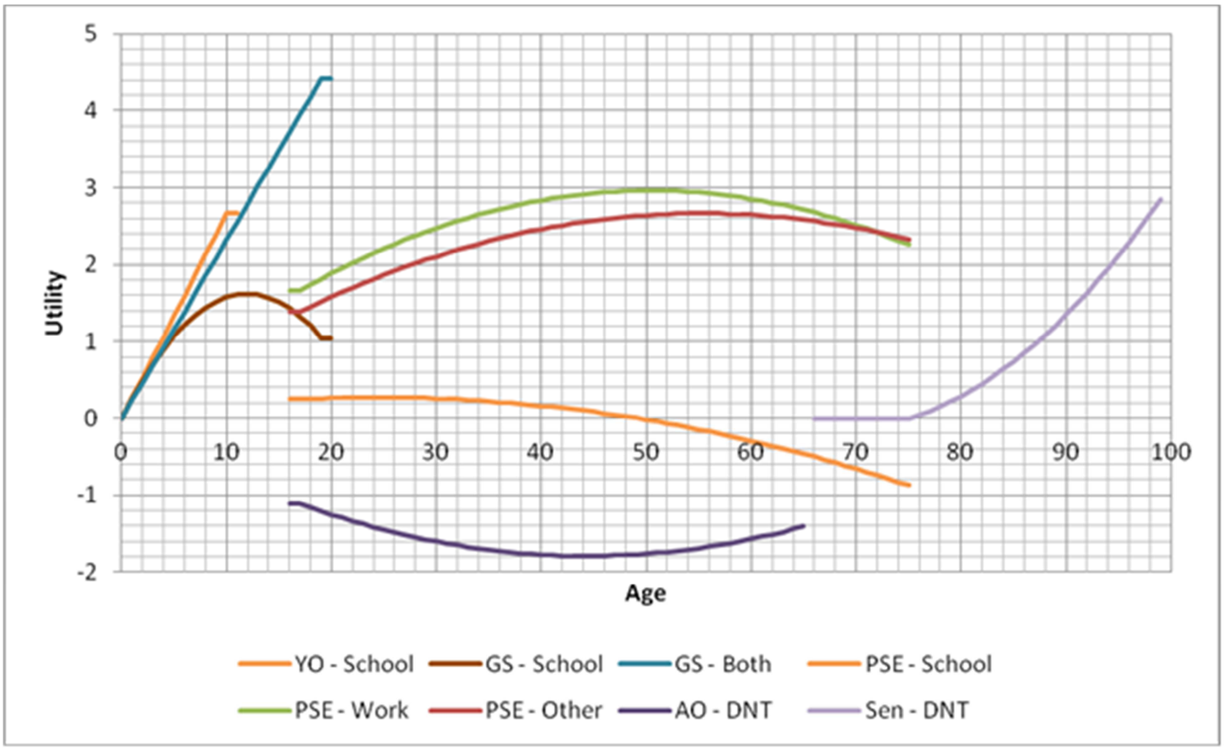
This is a complex model, with a wide range of sensitivities to person types, household and personal properties, household income, auto ownership and accessibilities. Some of the key sensitivities are as follows.

The alternative-specific constants indicate that in general, most person types have one or two favored roles; these are the appropriate and expected ones (workers tend to work, students tend to go to school, etc.). It should be noted that Youth Others had no observations of Both day patterns in the dataset, and so this parameter was set to an arbitrarily negative large number, to remove the alternative from consideration.

The employment parameters indicate that people who work at home are much less likely to choose a Work role (involving leaving the house to work); whereas, students with jobs are much more likely to choose either Work or Both work and school.

The age parameters are not straightforward to understand, due to the quadratic nature. The calculated results are shown in Figure 2.3 below. As youths and grade school students age, they are more likely to choose a School role, and grade school students are more likely to choose Both. Post-secondary students are less likely to choose School as they age, with an increasing utility of Work and Other. Adult Others are somewhat less likely to travel at younger and older ages, while for Seniors, there is a pronounced aging effect as older seniors are more likely to choose the None option and stay at home. It should be noted that the figure shows only the age component; the alternative-specific constants and other parameters also enter into the decision. For instance, for grade school students at age 18, there is an additional 4.5 utils assigned to the Both alternative and only 1 util for the School choice due to age. However, the alternative-specific constants are about -0.53 for Both and 6.43 for School, so School is still much more likely.

Figure 2.3 Day Role Choice Age Parameters



The makeup of the household has several effects on day patterns. For single parents and postsecondary students living alone, the effect is a lower utility of the None alternative (i.e., a more "active" day on average). On the other hand, for seniors living alone, and more significantly, in households with a worker or 3+ persons is linked with a greater likelihood of staying at home. Some seniors living alone will be living in some sort of care facility, which is consistent with less travel. Seniors living with workers or with 3+ persons may be seniors living with their adult children in an informal equivalent of residential care.

For children, the presence of a NWA (Non-Working Adult) in the household corresponds to an increase in both the Other and None day roles. This may in part reflect home-schooling, where one parent stays home and teaches the children. This effect is most significant for younger children, especially those 3+ who are not in school yet. Daycare is often represented as a school activity in travel surveys, so this reflects the expected result that children with all their parents working are much more likely to go to daycare.

Similarly, for adults, the presence of children tends to increase the utility of the Other and None day roles. In general, younger children (under 3) tend to result in greater utility of staying home, while older children tend to result in greater utility of the Other role. This reflects several family arrangements, including raising young children, homeschooling, and taking care of sick children. These roles are concentrated in Adult Others, and female Workers. (Male workers had very little effect in estimation.)

Workers in certain industries and occupations have increased or decreased utilities of choosing a Work role on the day. Increases were seen in Education and Health, and in Primary and Secondary industry groups, as well as in Managerial/Business occupations. Decreases were seen in the Leisure and Hospitality sector, as well as for workers in Sales, Food and Entertainment, Service (non-Sales) and Health occupations. These speak to the varying schedules and expectations for these workers. Because the CSTDM 2.0 is a weekday model, workers in areas like health, retail, hospitality and protective services who commonly work weekends would be expected to have fewer weekdays with Work roles; on the other hand, the more typical 9 to 5 jobs, like the managerial and business functions, education and manufacturing may require higher attendance during the weekdays.

Income has a strong effect on travel. In this day role part of the model, the effects are mostly expressed in an increase in the utility for the None choice to stay at home all day. Lower incomes are consistent with higher utilities for the None choice, with different effects seen based on the number of workers in the household, where higher incomes are needed to produce the same utility for households with higher numbers of workers. For instance, an income from $35,000 to $50,000 represents a significant decrease in the None alternative for households without workers, a modest decrease with one worker, no change for two worker households, and an increase in the None alternative (i.e., a reduction in travel) for 3+ worker households.

In addition to the household-level incomes, most person types were found to have additional utility for the None alternative (i.e., reduced travel) with lower incomes. This effect is stronger for seniors and children than for workers; a consistent and significant response was not seen for Adult Others or Postsecondary students. It expresses itself more as a reduction in travel for low income households, especially those earning $25,000 or less, rather than an increase in travel for high income households.

Additionally, workers were found to have a decreased utility of selecting a Work role in lower income households. This reflects the common sense observation that people who work less (and are thus less likely to choose a Work role for the day) typically make less money (and this live in lower income households). The structure of the model demands that the income be specified in the population synthesis and considered an input to this process; the correlation is honored in any case.

Low auto ownership has a travel-reducing role as well. All persons in households without cars showed an increase in the utility of the None day role, leading to less travel. This was particularly strong for young children and seniors, who may be the most captive, as well as post-secondary students and part-time workers, who may be the most flexible. Full-time workers and grade school students, with the most fixed schedules, had a lower response than other person types. It should also be noted that grade school students without cars or in insufficient car households had a large reduction in the utility of the Both alternative; high school students often either need a car to get to their jobs, or work at a job to be able to buy a car. These patterns generally continued, to a lesser degree, for insufficient car households.

Accessibility also plays a key role in the Day Role model. Grade school students experience the expected reduction in utility for the School alternative as the generalized cost of travel to school increases. The same is true for Workers without cars. On the other hand, Workers in households with cars experience no change in utility for the Work alternative until the workplace is quite difficult to get to from home; roughly the equivalent of 30 miles. This is not unreasonable; workers generally need to fulfill the work role on an ongoing basis, and it seems appropriate that they are not dissuaded by a moderate commute, although as commutes lengthen, alternatives such as telecommuting and rearranged work weeks may be considered as alternatives.

More generally, the logsum of SOV accessibility for shopping (as a proxy for accessibility to all nonwork, nonschool activities) represents a general local measure of accessibility, which is more appropriate for people without jobs or school locations. The utility of the Other day role showed a positive relationship with this for Workers and Post-Secondary Students; that is, persons in more accessible locations were more likely to choose this day role, although the effect is relatively small. For Adult Others and Seniors, a more robust effect was seen, where more accessible locations matched with reduced utility for the None day role, or a more active day. For Adult Others, this effect was minimal in low income households, but more significant for incomes over $25,000. For Seniors, on the other hand, the effect was actually more pronounced for the lowest income groups. This may in part be interacting with the significant low income effects for seniors, and counteracting these in areas of high accessibility. Walk access transit had a similar role for seniors; this was not seen for Adult Others, likely due to the high degree of correlation between transit and auto accessibility.

This Day Role model is applied to all persons, selecting a specific Role. If the selection is None (where no travel occurs, and thus only one day pattern is possible), or the selection is Both (a relatively small group, comprising roughly 1 percent of people), there is no specific Pattern Group model, and the person goes directly to the Pattern Choice Model. In the other cases: Work, School, and Other, the SDPTM then uses a Day Pattern Group Model to assign a specific Pattern Group to the person.

2.2 WORK DAY PATTERN GROUP MODEL

If the Day Role model chooses the Work alternative, then the SDPTM proceeds to select a Day Pattern Group from the 96 possible groups in the Work Day Pattern Group model set. These groups are shown in Table 2.5 below; the text before that table lays out the definition of these groups.

Table 2.5 Work Day Pattern Group Time Period Definitions

	Outbound Time Period:→				
↓ Return:	Early Off	AM Peak	Midday	PM Peak	Late Off
Early Off	PT Early	–	–	–	–
AM Peak	PT Early	PT Early	–	–	–
Midday	PT Early	PT Early	PT Early	–	–
PM Peak	FT Early	FT Peak	PT Late	PT Late	–
Late Off	FT Early	FT Late	PT Late	PT Late	PT Late

In deciding the grouping to use, the following general philosophy was used:

1. The amount of travel, in terms of trips and especially tours, is the most important thing to be determined in this model;
2. The arrangement of this travel into tours, subtours, diversion stops and so on, is a key aspect of an activity based model, and should be considered as well; and
3. The timing of the work tour is also quite significant, and should be included to the degree possible.

The Work Day Pattern Groups are divided into several dimensions; for ease of representation, the dimensions describing the number and time periods of work tours are collapsed into one. The work tour dimension has eight possible alternatives:

- The choice to have two or more work tours in a day (in practice, there are almost no observations of more than two work tours).
- The choice to have one work tour, with a work-based subtour; the work tour could be a "FT Peak" tour, where the person leaves home in the AM peak and returns home in the PM peak (about two thirds of these days), or the work tour could have another temporal pattern.
- The choice to have a single work tour, without a subtour; the work tour is then classified into five different time period possibilities. These include the FT Peak described above, corresponding FT Early (leaving home before the AM peak) and FT Late (returning home after the PM peak) time periods, and then two time period groups more consistent with part-time work; a PT Early where the work tour is complete before the start of the PM peak, and a PT Late where the work tour finishes after.

These time period groups are described in Table 2.5. Note that the FT Peak definition is the same for both with and without a work-based subtour. The division of observed patterns amongst these eight groups is shown in Table 2.6.

Table 2.6 Work Day Pattern Group Dimensions and Frequencies

Dimension	Proportion of Days
Work Tours and Time Periods	
1 work tour, no subtours, FT Peak	47.4%
1 work tour, no subtours, FT Early	6.4%
1 work tour, no subtours, FT Late	9.6%
1 work tour, no subtours, PT Early	10.2%
1 work tour, no subtours, PT Late	9.0%
1 work tour, with work-based subtour, FT Peak	7.0%
1 work tour, with work-based subtour, all other time periods	3.3%
2+ work tours, all time periods	7.1%
Number of Diversion Stops on Work Tour	
0 diversion stops	59.5%
1 diversion stop	19.9%
2+ diversion stops	20.6%
Number and Complexity of Nonwork Tours	
0 nonwork tours	76.1%
1 nonwork tour, 2 trips	15.0%
1 nonwork tour, 3+ trips	4.7%
2+ nonwork tours	4.1%

The second dimension concerns the number of diversion stops on the work tour itself (excluding stops made on a work-based subtour); there are three options, representing no diversion stops, one diversion stop, and two or more diversion stops. The division of observed patterns amongst these three groups is shown in Table 2.6.

The third dimension considers the number and complexity of other (nonwork) tours in the day; there are four options, representing no nonwork tours, one nonwork tour with two trips, one nonwork tour with 3+ trips, and two or more nonwork tours. The division of observed patterns amongst these four groups is shown in Table 2.6.

This resulting grouping defines 96 possible day pattern groups (8 × 3 × 4); the Work Day Pattern Group Choice model selects from amongst these. The observed frequency across all 96 day pattern groups is shown in Table 2.7 below.

Table 2.7 Overall Work Day Pattern Group Frequencies

Diversion Stops:		0 Stops				1 Stop				2+ Stops			
Nonwork Tours:			1 Tour				1 Tour				1 Tour		
Work Tours and Time Periods:		**0 Tours**	**2 Trips**	**3+ Trips**	**2+ Tours**	**0 Tours**	**2 Trips**	**3+ Trips**	**2+ Tours**	**0 Tours**	**2 Trips**	**3+ Trips**	**2+ Tours**
1 work tour, no subtours	FT Peak	25.8%	4.7%	1.2%	0.5%	6.5%	1.4%	0.4%	0.2%	5.3%	0.9%	0.3%	0.2%
	FT Early	3.6%	0.5%	0.1%	0.0%	1.0%	0.2%	0.0%	0.0%	0.7%	0.1%	0.0%	0.0%
	FT Late	3.7%	0.2%	0.0%	0.0%	2.5%	0.1%	0.0%	0.0%	2.8%	0.2%	0.1%	0.0%
	PT Early	3.3%	1.3%	0.5%	0.7%	0.8%	0.4%	0.2%	0.3%	1.6%	0.4%	0.2%	0.4%
	PT Late	3.6%	1.0%	0.4%	0.5%	1.0%	0.3%	0.1%	0.1%	1.3%	0.3%	0.2%	0.2%
1 tour, with subtour	FT Peak	2.8%	0.8%	0.2%	0.1%	1.2%	0.3%	0.1%	0.1%	1.0%	0.2%	0.1%	0.0%
	All other	1.0%	0.2%	0.1%	0.1%	0.8%	0.1%	0.0%	0.0%	0.9%	0.1%	0.0%	0.0%
2+ tours	All time periods	2.0%	0.5%	0.1%	0.1%	1.0%	0.2%	0.1%	0.1%	1.9%	0.6%	0.2%	0.2%

For user clarity and estimation simplicity, only a set of alternative-specific constants is specified for these 96 alternatives individually, which ensure the model matches the overall distribution for each choice. The remaining set of behavioral parameters applies to individual dimensions. For instance, a parameter may affect the utility of choosing a two or more work tour day; this parameter will then be applied to all 12-day pattern groups (3 number of diversion stops × 4 number of nonwork tours) that involve two or more work tours.

The alternative-specific constants for these alternatives are summarized in Table 2.8 below, and the behavioral parameters are listed in Tables 2.9 and 2.10 below.

Note: "Simple" day pattern groups (with an average of fewer than 3.5 trips) are highlighted in orange. "Complex" day pattern groups (with an average of 6.5 or more trips) are highlighted in teal. These categories are used in the Day Pattern Group Model Calibration, and described in the calibration Section 4.1, near the end of this document.

Table 2.8 Work Day Pattern Group Alternative-Specific Constants

Diversion Stops:		0 Stops				1 Stop				2+ Stops			
Nonwork Tours:		0 Tours	1 Tour		2+ Tours	0 Tours	1 Tour		2+ Tours	0 Tours	1 Tour		2+ Tours
Work Tours and Time Periods:			2 Trips	3+ Trips			2 Trips	3+ Trips			2 Trips	3+ Trips	
1 work tour, no subtours	FT Peak	2.0681	-0.3268	-1.6322	-2.3864	1.1339	-1.0006	-2.0265	-2.9955	1.4452	-1.0509	-1.8749	-2.3407
	FT Early	0.0000	-2.3437	-3.8299	-4.6418	-0.7244	-2.8722	-4.4293	-5.5734	-0.5472	-2.8100	-3.8480	-5.9308
	FT Late	-0.1744	-3.8038	-5.1963	-6.2001	-0.0766	-3.8405	-4.6399	-7.3273	0.4228	-2.5227	-3.9281	-4.8900
	PT Early	0.3169	-1.2459	-2.1894	-1.9712	-0.5355	-1.9968	-2.1799	-2.2708	0.6107	-1.5765	-1.4361	-1.6374
	PT Late	0.1996	-1.7430	-2.6654	-2.3749	-0.5852	-2.3776	-3.0688	-3.0786	0.1202	-1.6327	-2.2275	-2.2307
1 tour, with subtour	FT Peak	-0.2842	-2.3290	-3.2008	-3.7865	-0.6615	-2.7735	-3.5701	-4.1824	-0.3564	-2.7349	-2.6219	-4.5823
	All other	-1.3669	-3.9679	-4.8575	-4.4646	-1.2200	-4.0839	-4.7208	-5.3290	-0.5943	-3.2475	-3.9805	-5.0588
2+ tours	All time periods	0.1923	-1.6189	-2.9250	-3.4270	0.0902	-1.9563	-2.7719	-2.9937	1.3261	-0.6149	-1.4455	-1.5606

Table 2.9 Work Day Pattern Group Parameters: Work Tours and Time Periods

Attribute		FT Peak	FT Early	FT Late	PT Early	PT Late	Sub Other	Sub Peak	2+ Work
Person	Age under 35	0	-0.3167	0.2535	0	0.4405	0	0	0
	Age 55 or older	0	0	-0.1495	0.2839	0.2504	0	0	0
	Part-time	0	-0.8931	0	1.2222	1.1659	0	-0.2648	0.2980
	Nonworker	0	-0.6061	0.4816	1.8203	1.7679	0	0	0.5141
Occupation	Blue collar	0	0.7208	-0.3066	0.3063	0.1926	-0.1878	-0.8005	0.1621
	Clerical	0	-0.9539	-0.3409	-0.2646	-0.2717	0	0.3251	-0.2156
	Education	0	-1.4997	-0.2305	0	-0.7192	-1.2917	-1.2874	-0.4828
	Health	0	-0.5453	0.3428	0	0	0	-0.3768	0.3414
	Managerial/Bus	0	0	0.1855	-0.3057	-0.1494	-0.1538	0	0
	Prof./Tech	0	0	0	0	0	0	0	0
	Sales/Food/Ent	0	0	0.2348	0	0.8205	0	-0.6133	0.2103
	Service nonsales	0	0.7608	0	0.4413	0.5344	0	0	0.4258
Household	Single person	0	-0.3409	0.4414	-0.3528	0	0.8177	0.4548	0
	Female with child	0	-0.6652	-0.3601	0	-0.7840	0	0	-0.3165
	Male with child	0	0.3247	0	0	0	0	0	0
	No car or no license	0	0	0	0	0	-0.6954	0	-0.8059

Attribute		FT Peak	FT Early	FT Late	PT Early	PT Late	Sub Other	Sub Peak	2+ Work
Income	1 worker, <$25K	0	0.1033	-0.5241	0.2956	0.2854	-0.3662	-0.5174	0
	1 worker, $25-50K	0	0	-0.2344	0.1475	0.1463	-0.2746	-0.3577	0
	1 worker, $50-75K	0	0	0	0	0	0	0	0
	1 worker, $75-100K	0	0	0	0	-0.1555	0.4825	0.1796	0
	1 worker, $100K+	0	-0.3802	0.3018	-0.4619	-0.1555	0.5838	0.2570	-0.2905
	2+ workers, <$25K	0	0.1341	0	0.3074	0.5450	0	-0.7184	0.1838
	2+ workers, $25-50K	0	0	0	0	0	0	-0.4839	0.1596
	2+ workers, $50-75K	0	0	0	0	0	0	0	0
	2+ workers, $75-100K	0	0	0	-0.0955	0	0.2750	0.1559	-0.1945
	2+ workers, $100K+	0	-0.4045	0.2403	-0.1811	-0.1127	0.3223	0.3570	-0.3140
Accessibility	Logsum A: (portion to -1)	0	-0.0803	-0.1486	0.6984	0.6386	0.4467	-0.1171	1.4145
	B: (-1 to -2.5)	0	-0.4740	-0.1077	-0.0312	-0.1278	-0.3259	0.1729	0.3043
	C: (-2.5 or less)	0	-0.1746	0.0213	-0.2831	-0.0219	0.1429	0.2348	0.0308
	Work eat walk accessibility	0	0	0	0	0	0.02088	0.02088	0

Table 2.10 Work Day Pattern Group Parameters: Diversion Stops/Nonwork Tours

		Diversion Stops			Nonwork Tour			
Attribute		0 Stop	1 Stop	2+ Stops	0 Tours	1 Tour, 2 Trip	1 Tour, 3+ Trips	2+ Tours
Person	Age under 35	0	-0.2246	-0.2246	0	0	0	-0.4855
	Age: 55 or older	0	0	0	0	0	0	-0.2184
	Part-time worker	0	0.2305	0.2252	0	0.1027	0.1027	0.4200
	Work at home	0	0.4323	1.0135	0	0.1986	0.2420	0.6414
Household	Single person	0	0.3228	0.4116	0	0.1746	0.1746	0.2788
	Female, 1 kid, or 2+ with youngest < 6	0	0.2296	0.3609	0	0.2270	0.2270	1.0018
	Female, 2+ kids, both 6+	0	0.2296	0.3609	0	0.5223	0.5223	1.8240
	Male, 1 kid, or 2+ with youngest < 6	0	0	0	0	0.1429	0.1429	0.5467
	Male, 2+ kids, both 6+	0	0	0	0	0.3575	0.3575	0.9755
	No car or no license	0	-0.0699	-0.0699	0	-0.5984	-0.5984	-0.6951
	Insufficient cars	0	-0.1614	-0.1614	0	0	0	0

Attribute		Diversion Stops			Nonwork Tour			
		0 Stop	1 Stop	2+ Stops	0 Tours	1 Tour, 2 Trip	1 Tour, 3+ Trips	2+ Tours
Income	1 worker, <$25K	0	-0.3282	-0.1193	0	-0.1206	-0.1519	-0.4118
	1 worker, $25-50K	0	-0.1324	0	0	0	0	-0.1645
	1 worker, $50-75K	0	0	0	0	0	0	0
	1 worker, $75-100K	0	0	0.1604	0	0	0	0
	1 worker, $100K+	0	0	0.1534	0	0.2578	0	0
	2+ workers, <$25K	0	-0.8275	-0.2726	0	0	-0.1519	-0.4118
	2+ workers, $25-50K	0	-0.2123	0	0	0	0	-0.1645
	2+ workers, $50-75K	0	0	0	0	0	0	0
	2+ workers, $75-100K	0	0	0	0	0.2268	0	0
	2+ workers, $100K+	0	0.1583	0.2268	0	0	0	0
Accessibility	Home to work logsum	0	-0.0126	-0.0375	0	0.0722	0.0699	0.2149
	Home accessibility, midday shop walk	0	0	0	0	0.0703	0.0578	0.0736
	Home accessibility, midday shop SOV	0	-0.0927	-0.1408	0	0	0	0
	Work accessibility, midday shop SOV	0	0.0393	0.0393	0	0	0	0

There are a large number of responses to demographics, as well as to public policy, in this model structure. First, considering the eight types in the work tour and time group dimension, the following are the main trends:

- **FT Peak.** Used as the reference alternative, with no additional parameters. Other alternatives should be interpreted in comparison to this one; for instance, the education occupation parameters are all negative, meaning that FT Peak pattern groups have a higher utility for education workers, which is consistent with expectations.
- **FT Early.** Increased utility for blue collar and service non-sales workers (the latter are primarily custodial and protective services), as well as for men with children (this may represent dropping them at daycare), and low income workers. Lower utility for young workers, part-time workers and single workers, as well as workers in education, clerical and health occupations. Also lower utility for women with children, which may indicate a preference for the later departures of the FT peak alternative, as well as very high income workers.
- **FT Late.** These day pattern groups, with later working hours, tend to have an increased utility for health workers, managerial/business workers and sales/food/entertainment workers, as well as for single workers, and non-workers who nevertheless happen to have chosen a work day role on the

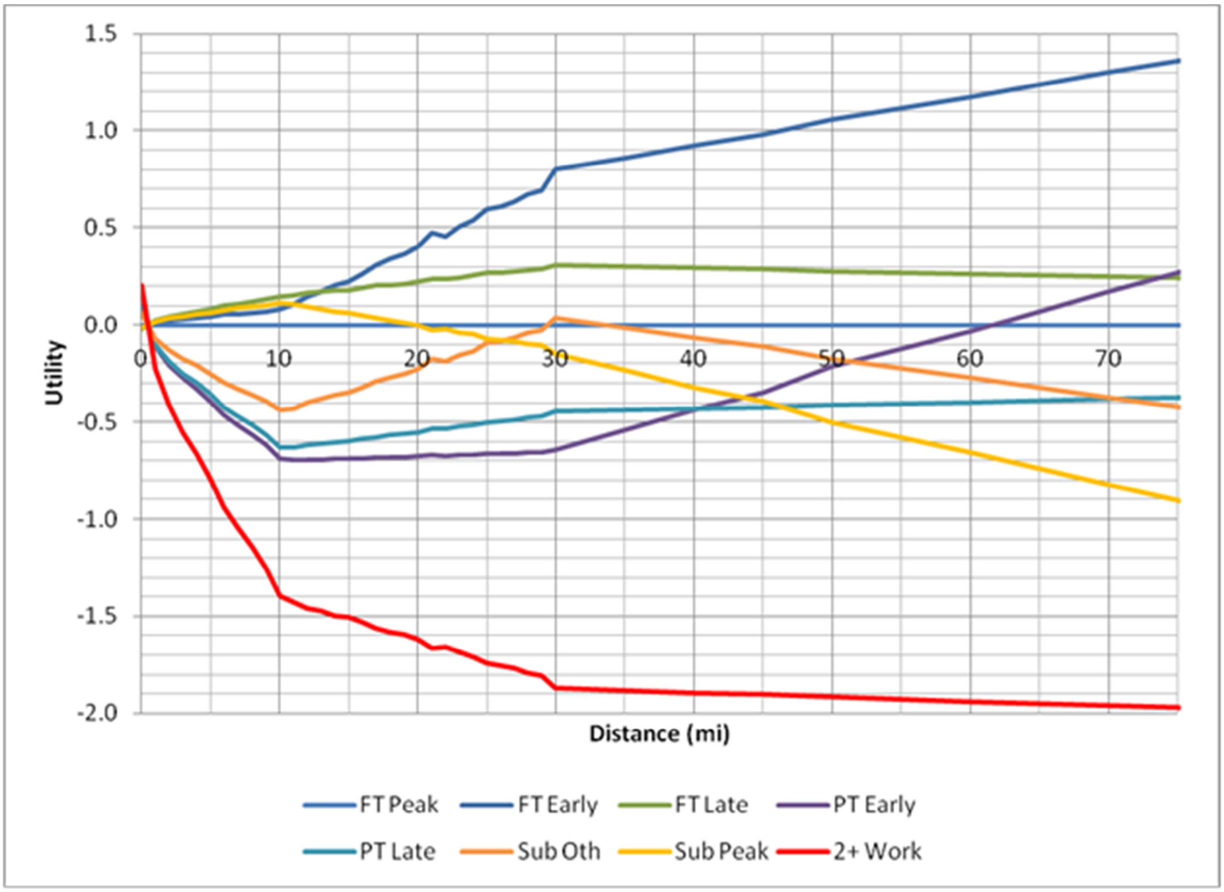
survey/simulation day. There is a consistent trend, where utility is positive for higher income workers and younger workers and the converse for lower income and older workers. The utility of these day pattern groups is also lower for blue collar, clerical and education workers, as well as for women with children, which is similar to the FT Late alternative.

- **PT Early**. For these day pattern groups, where work tends to take up less than the full day and is earlier in the day, the utility is strongly higher for part-time workers and non-workers. This alternative tends to also have higher utility for older workers and workers in blue collar and service non-sales occupations. The consistent income trend is highest for the lowest income workers, and declines from there. Single workers have reduced utility for this alternative, as do clerical and managerial/business workers.
- **PT Late.** This group, with shorter working hours concentrated in the evening has the same strong increased utility for part-time workers and non-workers. These alternatives also have higher utility for younger and older workers (as opposed to 35- to 54-year olds in the middle of their careers), and for blue collar, service non-sales and especially sales/food/entertainment workers. There is a similar consistent income pattern as PT Early, where the lower the household income, the greater the utility for these alternatives. These alternatives have lower utility for clerical, education and managerial/ business workers, as well as women with children.
- **Sub Peak**. Similar to FT Peak in hours, but containing a subtour as well – most frequently for lunch – these day pattern groups have higher utility for single workers (who may also be running errands on their lunch hour), as well as for clerical workers. These alternatives exhibit a consistent income trend, with high income workers preferring these versus those with lower incomes. Other factors with negative utility for this alternative include part-time workers as well as workers in education, blue collar, health and sales/ food/entertainment occupations.
- **Sub Other**. Comprising the day pattern groups with a subtour, but where the work tour is not an AM Peak/PM Peak tour, these groups have an increased utility for single workers, as well as a consistent increase in utility with higher incomes. The utility is lower for education workers, as well as slight decreases for blue collar and managerial/business workers. There is also a significant decrease in utility for persons in households without cars (or persons without driver's licenses), which indicates that the additional travel is onerous without cars: workers who travel in the peaks don't see the same effect.
- **2+ Work Tours.** Workers who make two work tours in a day are most frequently heading home for lunch. These groups have higher utility for part-time workers and non-workers who may be working multiple jobs on the day, as well as workers in blue collar, health, sales/food/entertainment and service other occupations. There is a consistent trend for greater utilities

for lower income workers for these alternatives, and lower utilities for higher income workers. Utility is also lower for working mothers, who travel more for other purposes, as well as for education and clerical workers. There is also a decrease in utility for people who cannot drive, again indicating a mobility limitation.

The accessibility component of these alternatives is primarily in a piecewise-defined logsum parameter, based on the medium income, sufficient auto simplified mode choice logsum for travel from the home to work (and back again). This is the same logsum used in the work location choice model; because these logsums are not directly comparable across income and auto ownership segments, the largest group was used as a proxy. The utility was defined in a piece-wise fashion, with breaks at logsum values of -1 and -2.5; these correspond to distances of roughly 10 and 30 miles to the work location, but because this is a multimodal logsum, the travel conditions across all modes factor into the value. Figure 2.4 below shows the utility against distance to work to provide a better understanding of the effect of these parameters; because the actual parameters use the full logsum rather than just distance, the curves show some roughness.

Figure 2.4 Work Day Pattern Group Accessibility: Work Tours and Time Periods



By far the strongest trend visible is for 2+ work tours, where there is a very strong reduction in utility for workers who have more onerous commutes. This is consistent with the idea of these day pattern groups largely consisting of workers going home for lunch. There is a decrease in utility for both part-time groups for shorter distances (consistent with workers in part-time jobs choosing work locations nearer to home), while both FT Early and PT Early have increased utility for long distance commutes; this may reflect workers leaving home earlier to get to work due to the length of the commute. Both subtour alternatives are reduced for these long commuting workers, which might indicate workers taking shorter lunches to leave earlier due to the length of their commute.

In addition to the home-to-work logsum discussed above, there is an increase in utility for workers who have a higher walk accessibility to eat during the midday. This uses the accessibility to all zones for the midday time period for eat purposes by the walk mode, as used in the Other Tour Mode choice model. Workers in busy downtowns are thus more likely to go out for lunch as compared with their rural or suburban colleagues.

The parameters affecting the other dimensions of the work day pattern groupings, the number of diversion stops and the number of nonwork tours, are internally consistent. The reference case of 0 was set for the no stop and no nonwork tour day pattern group alternatives, and the resulting behavioral parameters are either consistent for the other alternatives, or in some cases, increasing/decreasing as the days get more complex. For instance, workers at home have an additional 0.4323 utils for the 1 diversion stop alternatives, and 1.0135 for the 2+ alternatives (i.e., these workers have an increasing utility for more diversion stops).

Diversion stops are also increased for part-time workers and single workers, who are able to or have to run additional errands on their work tour. The utility is also increased for working mothers, who are often assigned many household tasks, or could be dropping children off at daycare. The utility of more stops is generally consistent with respect to income; higher for high income workers, and reduced for lower incomes, although low income workers have a larger disutility for 1 stop versus two or more; this may represent a decrease in casual stops in favor of significant additional travel or none at all. The utility of diversion stops is also reduced for younger workers and also for workers without a sufficient number of cars, that is, the number of cars equals the number of workers. This reflects decreased mobility amongst this population.

For nonwork tours, there is a strong increase in the utility of making more or more complex nonwork tours for parents; this is stronger for women than men, and stronger for parents of multiple children 6 and older, who tend to be active household members. The utility is also higher for single workers, part-time workers and workers at home, who generally have more opportunities and demands to engage in other activities. There is a slight income trend, where lower incomes in particular have a reduction in nonwork tours – this is consistent with the Day Role choice model. There is a decrease in utility for the heaviest travel days for younger workers, who may have fewer commitments, and older workers, who may not have a more relaxed pace to their lives. There is a very strong reduction in these utilities for workers who do not have the possibility of driving.

In explicit accessibility measures, there are several dimensions considered. The home-to-work simplified mode choice travel to work logsum for medium income, sufficient auto households was used; the same logsum measure as in the number and time of work tour dimension above. This logsum, as a composite utility, has a negative value, becoming more negative as the commute gets more onerous. There are two counteracting effects; for workers who have a longer commute, the utility of making diversion stops increases, and increases more strongly for multiple diversion stop alternative. On the other hand, the utility for nonwork tours decreases as the workplace is farther away, especially for multiple nonwork tours. In other words, workers with long commutes are relatively more likely to make additional stops on the work tour, while those with short commutes are more likely to make additional tours entirely instead. This interaction produces something of the effect of a time budget.

There are also three accessibilities, which use the accessibility to all zones for the midday time period for shop purposes, as used in the Other Tour Mode Choice model. This is a proxy for general shopping accessibility, and indeed, for overall accessibility. For diversion stops, the utility of additional stops decreases as the SOV accessibility at home increases, but the utility of additional stops increases as the SOV accessibility at the work location increases. In other words, workers who work in a more accessible location than they live have an increase in the utility of making a diversion stop. This effect is strongest for rural workers who commute into a city; they are in town already for work, so they are more likely to do other tasks. There is also a home-based walk accessibility for nonwork tours, where workers in more accessible locations will tend to make additional nonwork tours. This produces an interesting (and realistic) policy response: a desired goal is often to have a workforce living in highly accessible areas close to their workplaces – the population will take advantage of this attractive situation to produce more trips.

2.3 SCHOOL DAY PATTERN GROUP MODEL

The School Day Pattern Group Model is similar in structure to the Work Day Pattern Group Model; it divides the possible set of day pattern groups in three dimensions, with alternative-specific constants for 60 specific day pattern groups, and then a series of marginal behavioral parameters that affect the utility for one dimension at a time. The group structure is enumerated in Table 2.11 below, and the text before that table describes the dimensions individually.

Table 2.11 School Day Pattern Group Time Period Definitions

	Outbound Time Period:→				
↓ Return:	Early Off	AM Peak	Midday	PM Peak	Late Off
Early Off	Daytime	–	–	–	–
AM Peak	Daytime	Daytime	–	–	–
Midday	Full Early	Full Early	Daytime	–	–
PM Peak	Full Late	Full Late	Daytime	Evening	–
Late Off	Evening	Evening	Evening	Evening	Evening

The dimensions for this model are also similar to those for the work model; one dimension describing the number of school tours and the time periods of the school tour, one describing the number of diversion stops, and a third describing the number and complexity of non-school tours in the day pattern group. These latter two are the same as the work model; 0, 1, and 2+ diversion stops, and 0, 1 two-trip, 1 three-plus-trip and 2+ non-school tours.

The school tours and time periods dimension is simpler than that for work, because school tours were found in the analysis to be generally simpler, and more concentrated in terms of time periods; about 80 percent of school tours involve one of the two most common possible time period combinations; outbound in the AM peak, and return in midday or PM peak. (In contrast, for work, the two most common time periods combine for around 65 percent of tours.) The 2+ tour division was maintained; this is particularly important for describing the amount of travel. There was little evidence of school-based subtours in the day pattern dataset, so these were not broken into specific groups. The one-tour school days were divided into four time periods; as mentioned above, school travel is more tightly grouped than work. The Full Early and Full Late day pattern groups involve travel to school during or before the AM peak, and returning home in the midday or PM peak, respectively. Tours that take place primarily during the day are assigned to the Daytime pattern groups, and those that take place primarily in the evening are assigned to the Evening pattern groups. Table 2.12 below summarizes these time period groups.

As mentioned above, the second and third dimensions of the day pattern grouping are the same as those for the work day pattern group model. The division of observed patterns amongst all three dimensions is shown in Table 2.12.

Table 2.12 School Day Pattern Group Dimensions and Frequencies

Dimension	Proportion of Days
School Tours and Time Periods	
1 school tour, Full Early	33.4%
1 school tour, Full Late	50.9%
1 school tour, Daytime	5.9%
1 school tour, Evening	6.1%
2+ school tours, all time periods	3.8%
Number of Diversion Stops on School Tour	
0 diversion stops	73.4%
1 diversion stop	14.5%
2+ diversion stops	12.1%
Number and Complexity of Nonschool Tours	
0 nonschool tours	76.4%
1 nonschool tour, 2 trips	15.3%
1 nonschool tour, 3+ trips	4.6%
2+ nonschool tours	3.6%

This resulting grouping defines 60 possible day pattern groups (5 × 3 × 4); the School Day Pattern Group Choice model selects from amongst these. It can be seen that the simpler school day pattern groups (i.e., those involving fewer trips) are more common than in the same groupings of work day patterns. The observed frequency across all 60 day pattern groups is shown in Table 2.13 below.

As with the work day pattern group choice model, only a set of alternative-specific constants is specified for these 60 alternatives individually, to ensure the model matches the overall distribution for each choice. The remaining set of behavioral parameters applies to individual dimensions. For instance, a parameter may affect the utility of choosing a 1 diversion stop day; this parameter will then be applied to all 20 day pattern groups (5 number of school tours/time periods × 4 number of non-school tours) that involve a single diversion stop.

The alternative-specific constants for these alternatives are summarized in Table 2.14 above, and the behavioral parameters are listed in Tables 2.15 and 2.16 below.

Table 2.13 Overall School Day Pattern Group Frequencies

Diversion Stops:		0 Stop				1 Stop				2+ Stops			
Nonschool Tours:			1 Tour				1 Tour				1 Tour		
School Tours/ Time Periods:		0 Tour	2 Trips	3+ Trips	2+ Tours	0 Tour	2 Trips	3+ Trips	2+ Tours	0 Tours	2 Trips	3+ Trips	2+ Tours
1 school tour	Full Early	20.4%	5.4%	1.8%	1.2%	1.6%	0.7%	0.2%	0.3%	1.3%	0.3%	0.2%	0.2%
	Full Late	30.3%	5.0%	1.1%	0.4%	6.7%	1.1%	0.3%	0.1%	4.9%	0.7%	0.3%	0.1%
	Daytime	2.3%	0.9%	0.1%	0.3%	0.8%	0.2%	0.0%	0.1%	0.7%	0.2%	0.2%	0.2%
	Evening	1.3%	0.3%	0.1%	0.4%	1.3%	0.0%	0.1%	0.1%	2.3%	0.1%	0.1%	0.0%
2+ tours	All time periods	1.6%	0.2%	0.2%	0.2%	0.6%	0.1%	0.1%	0.1%	0.4%	0.1%	0.1%	0.0%

Table 2.14 School Day Pattern Group Alternative-specific Constants

Diversion Stops:		0 Stop				1 Stop				2+ Stops			
Nonschool Tours:			1 Tour				1 Tour				1 Tour		
School Tours/ Time Periods:		0 Tour	2 Trips	3+ Trips	2+ Tours	0 Tour	2 Trips	3+ Trips	2+ Tours	0 Tour	2 Trips	3+ Trips	2+ Tours
1 school tour	Full Early	-0.6027	-2.0288	-3.0444	-3.5652	-2.7230	-3.7643	-5.0082	-4.7045	-2.6685	-4.4903	-4.8655	-5.1802
	Full Late	-0.0635	-1.9351	-3.3933	-4.3800	-1.1687	-3.0758	-4.3818	-5.2416	-1.1597	-3.2497	-4.1693	-5.0863
	Daytime	-3.6400	-4.8410	-6.7520	-6.4903	-4.5116	-6.1596	-7.7385	-7.7944	-4.3528	-6.2748	-6.1143	-7.0920
	Evening	-4.1678	-5.8667	-6.7049	-6.2539	-3.8110	-8.0010	-7.2938	-7.5747	-3.0253	-6.8158	-6.6954	-9.1868
2+ tours	All time periods	-3.3073	-5.5952	-5.8345	-6.1678	-3.9448	-6.3688	-6.3249	-7.3154	-4.0269	-5.7830	-6.3442	-7.9014

Note: "Simple" day pattern groups (with an average of fewer than 3.5 trips) are highlighted in orange. "Complex" day pattern groups (with an average of 6.5 or more trips) are highlighted in teal. These categories are used in the Day Pattern Group Model Calibration, and described in the calibration Section 4.1, near the end of this document.

Table 2.15 School Day Pattern Group Parameters: School Tours and Time Periods

Attribute		Full Early	Full Late	Daytime	Evening	2+ Tours
Status	Postsecondary student	0	-0.4562	2.3241	1.5743	1.6225
	Nonstudent, < 18	0	0.6091	0.8022	1.3466	1.1508
	Nonstudent adult	0	0	2.8704	1.9959	1.8686
	With job, HS student	0	0	-0.7067	0	0
	With license and HH has a car, HS student	0	-0.1322	1.4267	0.6636	0.9021
	With full-time job, postsecondary student	0	0.4574	0	0.8247	0
Age	0 to 5 years old	0	-0.1945	1.5311	0	-0.4129
	6 to 10	0	-0.1177	-0.5067	0	-0.7910
	11 to 14	0	0	0	0	0
	15 to 17	0	0	-0.3740	0	0
	18 to 22	0	0	0	0	0
	23 to 29	0	0.3822	0	0.6037	0
	30+	0	-0.4627	-0.5430	0	-0.8501
Household	Single, postsecondary	0	0	-0.3214	0	0.8025
	HH has nonworking adult, Grade School stud. age < 7	0	-0.9448	0	-1.2624	-0.3998
	HH has NWA, GS 7-11	0	-0.2569	-0.9074	-0.4975	0
	HH has NWA, GS 12+	0	0	-0.3018	-0.2171	0
	No car in HH	0	0	0	0	-1.3030
Income	<$25K	0	0	0	0	-0.5040
	$25-50K	0	0	0	0	-0.9335
	$50-75K	0	0	0	0	-0.2040
	$75-100K	0	0	0	0	0
	$100K+	0	0	0	0	0.4859
Acc.	H-S logsum, K-8	0	0	0	0	0.9436
	H-S logsum, HS	0	0	0	0	1.7928
	SOV time to school, PSE	0	0	0	0	-0.0425

Table 2.16 School Day Pattern Group Parameters: Diversion Stops/Non-school Tours

Attribute		Diversion Stops			Non-school Tours			
		0 Stop	1 Stop	2+ Stops	0 Tours	1 Tour, 2 Trip	1 Tour, 3+ Trips	2+ Tours
Status	Postsecondary student	0	-0.2852	-0.2852	0	0	0	0
	Nonstudent age < 18	0	0	0	0	-0.3932	-0.3932	-1.3055
	With job, HS student	0	0	0	0	0.3532	0.3532	0.6121
	With license and HH has a car, HS student	0	0.2774	0.2368	0	0.3038	0.3848	1.3519
Age	0 to 5 years old	0	0.4026	0.3611	0	0	0	1.1073
	6 to 10	0	0.1450	0.2962	0	0	0	0
	11 to 14	0	0	0	0	0	0	0
	15 to 17	0	-0.1269	-0.1269	0	0	0	0
	18 to 22	0	0	0	0	0	0	0
	23 to 29	0	0.3034	0.3034	0	0.2361	0.2361	0.9159
	30+	0	0.5996	0.9662	0	0.6742	0.7419	1.9314
Household	Single, postsecondary	0	0	0	0	0.2930	0.2930	0.2930
	HH has NWA, GS < 7	0	-0.4415	-0.4415	0	0	0	0
	HH has NWA, GS 7-11	0	-0.2775	-0.2775	0	0	0	0
	HH has NWA, GS 12+	0	0	0	0	0.2930	0.2930	0.2930
	Insufficient cars in HH	0	-0.092	-0.092	0	-0.130	-0.130	-0.130
	No car in HH	0	-0.4709	-0.4709	0	-0.6763	-1.3294	-1.1875
Income	<$25K	0	-0.3232	-0.5572	0	-0.3970	-0.5633	-0.7382
	$25-50K	0	-0.2781	-0.2781	0	-0.4412	-0.2814	-0.5940
	$50-75K	0	-0.1045	-0.1045	0	-0.1641	-0.1641	-0.1641
	$75K+	0	0	0	0	0	0	0
Access	H-S logsum, K-8	0	-1.3172	-1.3172	0	0.3560	0.3560	0.3560
	H-S logsum, HS	0	0	0	0	1.3213	1.3213	1.3213
	SOV time to school, PSE	0	0	0.0096	0	0	0	-0.0216
	Home Other Logsum	0	-0.0358	-0.0358	0	0	0	0

These models are complex, responding to changes in demographics, as well as to public policy with this structure. First, considering the five types in the school tour and time group dimension, the following are the main trends:

- **Full Early**. Used as the reference alternative, with no additional parameters. Other alternatives should be interpreted in comparison to this one; for instance, nonstudents under the age of 18 have a positive utility for all other alternatives, indicating that the Full Early alternatives have a low utility as much as that the other alternatives have high utilities.
- **Full Late.** The standard school day, with return home in the PM peak. These alternatives have primarily reductions in utility; for postsecondary students without jobs, for grade school students with driver's licenses, and for younger children, especially with a nonworking adult in the household, who could pick the child up from school and thus avoid the need for afterschool daycare.
- **Daytime.** Strongly more common for postsecondary students and nonstudents – especially adults, this group of alternatives also has an increased utility for young children, who are likely attending daycare or preschool, as well as for high school students with licenses, although this is offset if the student also has a job. This alternative group also has a reduction in utility for
- **Evening.** Similar in some ways to the daytime group, in that it represents a less conventional school tour, the evening group of alternatives has high utility for postsecondary and nonstudents, as well as for high school students with a license or a job (or, additively, both). These alternative groups have a strong reduction in utility for children in households with nonworking adults.
- **2+ Tours.** The group of alternatives that represents increased school travel, these alternatives have much more complex utility functions than the other school tour/time period groups. These alternatives have a relatively high utility for postsecondary students and nonstudents, as well as high school students who drive. There is a reduction in utility for young children, especially when the household also has a nonworking adult. There are also sensitivities to other properties; there is a strongly reduced utility if the household has no car, and it is more attractive for higher income households (and consistently, less so for lower income households). The travel cost from home to the school is also important; for grade school students, the simplified mode choice logsum for travel to the school (as used in the school location choice model) is used. Specifically, the logsum for age 10- to 14-year olds in households with sufficient autos is used for grade school students; for postsecondary students, the SOV travel time to school is used. The logsum used for grade school students gets more negative as travel is more onerous, while the SOV time is a positive number, so all three of these travel costs

express the same concept; students who attend school close to home have an increased likelihood of making more school tours.

The presence and number of diversion stops on the school tour is conditioned by a number of factors, many of which are similar to the factors affecting diversion stops on work tours. Diversion stops are more common for older and younger students; older students have more complex demands on their time, while younger students may be accompanying their parents on errands on the way to or from school. This is consistent with the effect that a nonworking adult in the household tends to reduce the utility of diversion stops – the adult is either accomplishing the errands while the child is in school, or a working adult is doing these tasks while the nonworking adult only travels to pick up the child.

The likelihood of making these additional diversion stops is also reduced for lower income households, and for households with insufficient, or especially, no cars. There is also a strong sensitivity to the travel costs from home to school for grade school students in grades K-8, and a weak one for postsecondary students; in both cases, the more costly the tour from home to school and back, the more likely additional stops are to be made on the tour. There is also a negative effect from the Other logsum at the home end; this indicates that people living in accessible locations are less likely to make additional stops on the school tour. The other logsum is a generalized multimodal accessibility to all nonwork-non-school destinations; the function is explained in the Other Day Pattern Group Choice Model below.

For non-school tours, there are also several similarities to the nonwork tour aspect of the Work Day Pattern Group Choice Model, as well as to the parameters in the diversion stop dimension; some demographics simply have more travel than others. This includes older students who often have other priorities in their lives and demands on their time, as well as single postsecondary students who have to maintain their households, and high school students with cars (greater mobility) and jobs (additional responsibility, as well as more money to pursue leisure).

Additional non-school tours are suppressed for persons in lower income households, as well as those without sufficient cars – and especially for those without cars at all. This reduction in mobility translates into reduced travel in this model. The travel to school also has a role to play; students with easier commutes – especially high school students – are more likely to make more non-school tours, in the same way that they are more likely to make multiple school tours.

2.4 OTHER DAY PATTERN GROUP MODEL

The Other Day Pattern Group Model is similar to the Work and School models structurally, in that it consists of alternative-specific constants for the 189 alternatives, as well as behavioral parameters affecting individual dimensions, but the grouping of possible days into day pattern groups is quite different. Table 2.17 below shows the entire set of patterns, and the text that follows describes them.

Table 2.17 Other Day Pattern Group Time Period Definitions; One Tour Days

↓ Return:	Outbound Time Period:→				
	Early Off	**AM Peak**	**Midday**	**PM Peak**	**Late Off**
Early Off	Early	–	–	–	–
AM Peak	Early	Early	–	–	–
Midday	Early Midday	Early Midday	Midday	–	–
PM Peak	Full Day	Full Day	Midday Late	Evening	–
Late Off	Full Day	Full Day	Midday Late	Evening	Evening

The first dimension of concern for other day patterns is the total number of tours. The pattern groups support 1 tour, 2 tours, 3 tours, 4 tours and 5+ tours as possibilities. Each set of tours is also subdivided by the number of trips; the alternative groups represent the minimum amount of travel, slightly more complex days with one or two extra trips (only one extra trip in the 1 tour case), or significantly more complex days with several extra trips. For example, for 3 tour days, these alternatives are to make 6 or fewer trips, 7 or 8 trips, or 9+ trips. The reason for the "or fewer" qualification is that some days involve a person being out of home at the start or end of the survey day, so a person could make three tours with five trips on the survey day, and then return home from the third tour on the next day.

The other two dimensions that are considered in this model are the purpose(s) of Other tours, and the times of the tours. As the number of tours rises, the range of possible days get more complex (while the number of observations gets smaller), so there are three different definitions of these dimensions, for 1 tour days, 2 tour days and 3+ tour days, of necessity getting simpler with each additional tour.

One tour days are the simplest days, but the most common, comprising 60.5 percent of observed days. For one tour days, the six other activities are each considered as alternatives for the tour purpose dimension. These six purposes are escort, shop, personal business, social, recreation and eat. For time, six time periods are defined, as shown in Table 2.17.

As alluded to earlier, there are three possible numbers of trips for each one tour day; 2 trips, 3 trips or 4+ trips. This enables a total of 108 one-tour day pattern groups (6 purposes × 6 time periods × 3 numbers of trips).

For two tour days, 27.3 percent of Other days, there are two tours, which may have different purposes and time periods, so the detailed classification of one tour days was not possible. The purpose dimension was simplified; the six purposes were collapsed into three:

1. Escort ("Esc");
2. Maintenance ("Main"), containing Shop and Personal Business; and
3. Discretionary ("Disc"), containing Social, Recreation, and Eat.

The resulting purpose dimension for two tours are the six possible combinations of these activities; Esc-Esc, Esc-Main, Esc-Disc, Main-Main, Main-Disc, Disc-Disc. These are combinations, not permutations; the Main-Disc group includes all two-tour days where one tour purpose is maintenance and the other discretionary, regardless of order.

The temporal dimensions are also simplified to handle the increasing complexity. The six time periods defined for one tour days are simplified into two:

1. "Daytime" which includes Early, Early Midday, Midday and Full Day tours; and
2. "Night" which includes Midday Late and Evening tours.

There are thus three possible groups of tours by time; both tours in the daytime, one in the daytime and one at night, and both tours at night, including also the division of two tour days into days with 4 or fewer trips, 5 or 6 trips and 7+ trips yields a total of 54 day pattern groups (6 purpose combinations × 3 time period combinations × 3 numbers of trips).

For three tour, four tour and five-plus tour days, the complexity increases again, as the sample size reduces. These represent 8.7 percent, 2.6 percent, and 1.0 percent of days, respectively. In these cases, the time period structure was too complex to represent with subgroups, so the only dimension is by purpose. For these days, the three purposes defined in two tour days were kept; escort, maintenance and discretionary. Each day was classified in terms of the purpose with the most out-of-home activities, with ties being broken using the hierarchy provided (i.e., escort first, maintenance second). Considering also the number of trips (the minimum, one or two more, three plus more), this yields a total of 9 alternatives for each of three, four and five-plus tours (3 purposes × 3 numbers of trips).

The Other Day Pattern Groups are summarized in Tables 2.18 and 2.19 below; the percentages indicate the frequency of patterns in the survey data.

Table 2.18 Other Day Pattern Group Distributions; One Tour Days

Purpose and Time Period	2 Trips	3 Trips	4+ Trips
Escort			
Early	0.91%	0.14%	0.07%
Early Midday	0.80%	0.25%	0.33%
Full Day	1.09%	0.37%	0.63%
Midday	0.76%	0.24%	0.20%
Midday Late	0.41%	0.21%	0.48%
Evening	0.69%	0.16%	0.17%
Shop			
Early	0.62%	0.13%	0.05%
Early Midday	0.68%	0.48%	0.52%
Full Day	0.07%	0.14%	0.34%
Midday	4.09%	1.29%	0.90%
Midday Late	0.93%	0.81%	1.15%
Evening	2.27%	0.67%	0.46%
Personal Business			
Early	0.80%	0.13%	0.04%
Early Midday	1.60%	0.81%	0.98%
Full Day	0.99%	0.42%	0.77%
Midday	2.44%	1.23%	1.23%
Midday Late	1.14%	0.83%	1.64%
Evening	1.41%	0.45%	0.39%
Social			
Early	0.29%	0.04%	0.02%
Early Midday	0.70%	0.21%	0.28%
Full Day	0.71%	0.25%	0.44%
Midday	0.85%	0.26%	0.13%
Midday Late	1.02%	0.48%	0.43%
Evening	1.56%	0.28%	0.11%
Recreation			
Early	0.30%	0.06%	0.02%
Early Midday	0.71%	0.28%	0.17%
Full Day	0.45%	0.21%	0.19%

Purpose and Time Period	2 Trips	3 Trips	4+ Trips
Midday	0.79%	0.22%	0.08%
Midday Late	0.88%	0.38%	0.27%
Evening	1.13%	0.16%	0.09%
Eat			
Early	0.21%	0.05%	0.01%
Early Midday	0.21%	0.12%	0.17%
Full Day	0.46%	0.18%	0.25%
Midday	0.79%	0.28%	0.14%
Midday Late	0.33%	0.27%	0.35%
Evening	1.06%	0.32%	0.07%

Table 2.19 Other Day Pattern Group Distributions; 2+ Tour Days

Purposes and Time Periods	4 Trips	5 or 6 Trips	7+ Trips
A. 2 Daytime			
Esc-Esc	1.28%	0.35%	0.11%
Esc-Main	0.39%	0.27%	0.14%
Esc-Disc	0.20%	0.15%	0.03%
Main-Main	0.68%	0.47%	0.17%
Main-Disc	0.64%	0.64%	0.18%
Disc-Disc	0.14%	0.12%	0.01%
B. Daytime/Night			
Esc-Esc	1.33%	0.64%	0.41%
Esc-Main	0.72%	0.66%	0.34%
Esc-Disc	0.63%	0.49%	0.22%
Main-Main	1.48%	1.84%	0.85%
Main-Disc	2.27%	2.32%	1.07%
Disc-Disc	1.13%	1.04%	0.38%
C. 2 Night			
Esc-Esc	0.09%	0.04%	0.06%
Esc-Main	0.10%	0.05%	0.09%
Esc-Disc	0.14%	0.09%	0.07%
Main-Main	0.28%	0.31%	0.17%

Purposes and Time Periods	4 Trips	5 or 6 Trips	7+ Trips
Main-Disc	0.59%	0.50%	0.34%
Disc-Disc	0.31%	0.19%	0.12%
3+ Tour Days			
Most common purpose	6 trips	7 or 8 trips	9+ trips
Escort	1.59%	1.02%	0.43%
Maintenance	1.01%	1.87%	1.23%
Discretionary	0.71%	0.65%	0.16%
4 Tour Days			
Most common purpose	8 trips	9 or 10 trips	11+ trips
Escort	0.55%	0.44%	0.24%
Maintenance	0.25%	0.47%	0.34%
Discretionary	0.13%	0.10%	0.04%
5+ Tour Days			
Most common purpose	10 trips	11 or 12 trips	13+ trips
Escort	0.18%	0.21%	0.18%
Maintenance	0.08%	0.13%	0.12%
Discretionary	0.02%	0.02%	0.01%

The alternative-specific constants for these alternatives are summarized in Tables 2.20 and 2.21 below, and the behavioral parameters are listed in Tables 2.22 to 2.25 below. Note: "Simple" day pattern groups (with an average of fewer than 3.5 trips) are highlighted in orange. "Complex" day pattern groups (with an average of 6.5 or more trips) are highlighted in teal. These categories are used in the Day Pattern Group Model Calibration, and described in the calibration Section 4.1, near the end of this document.

Table 2.20 Other Day Pattern Group Alternative-specific Constants; One Tour Days

Purpose and Time Period	2 Trips	3 Trips	4+ Trips
Escort			
Early	0.6358	-0.5204	-0.3285
Early Midday	0.1629	-0.0614	1.1992
Full Day	-0.0184	-0.2481	1.9796
Midday	0.0676	-0.0999	0.7939
Midday Late	-0.4366	-0.6235	1.6979
Evening	-0.1728	-0.7065	0.5383
Shop			
Early	-0.0470	-0.7594	-0.6268
Early Midday	0.0730	0.4753	1.5139
Full Day	-2.4067	-0.7071	1.2545
Midday	1.6951	1.1328	2.0061
Midday Late	0.3613	0.9713	2.4796
Evening	1.4934	0.8488	1.6781
Personal Business			
Early	0.1722	-1.2196	-1.2301
Early Midday	0.8936	0.6635	1.9369
Full Day	0.7056	0.0881	2.0142
Midday	1.1220	1.0103	2.2245
Midday Late	0.6047	0.8692	2.6220
Evening	0.9299	0.2375	1.2490
Social			
Early	-0.1539	-1.8746	-1.4971
Early Midday	0.3626	-0.1164	1.2525
Full Day	0.3843	-0.1652	1.8724
Midday	0.6871	0.4033	0.5243
Midday Late	0.8774	0.7621	1.7594
Evening	1.2643	0.1848	0.5808
Recreation			
Early	-0.7993	-1.8995	-2.2807
Early Midday	-0.2448	-0.6129	0.2918

Purpose and Time Period	2 Trips	3 Trips	4+ Trips
Full Day	-0.6662	-0.8276	0.3652
Midday	0.0908	-0.4706	-0.3331
Midday Late	0.2878	0.1017	0.8986
Evening	0.7449	-0.7482	0.0933
Eat			
Early	-0.9093	-1.7175	-2.3486
Early Midday	-1.1677	-1.0573	0.7346
Full Day	-0.7447	-0.7466	0.8443
Midday	0.2530	-0.2212	0.1529
Midday Late	-0.3383	-0.2330	1.6618
Evening	0.8026	0.2064	0.4887

Table 2.21 Other Day Pattern Group Alternative-Specific Constants; 2+ Tour Days

Purposes and Time Periods	4 Trips	5 or 6 Trips	7+ Trips
A. 2 Daytime			
Esc-Esc	-0.0741	-0.9123	-0.7042
Esc-Main	-1.6904	-1.1392	-1.1095
Esc-Disc	-1.7453	-1.8337	-2.2375
Main-Main	-0.4584	-0.3791	-0.4091
Main-Disc	-0.5921	-0.0126	-0.3032
Disc-Disc	-1.4796	-1.3949	-2.3579
B. Daytime/Night			
Esc-Esc	0.1809	0.2030	0.7930
Esc-Main	-0.6664	-0.1385	0.0697
Esc-Disc	-0.6061	-0.3034	-0.0728
Main-Main	0.8273	1.4294	1.6235
Main-Disc	1.0617	1.5732	1.9307
Disc-Disc	0.7714	1.1913	1.0191
C. 2 Night			
Esc-Esc	-2.5312	-2.9119	-0.9175
Esc-Main	-2.5094	-2.4315	-0.6249
Esc-Disc	-1.8509	-1.6245	-1.6610

Purposes and Time Periods	4 Trips	5 or 6 Trips	7+ Trips
Main-Main	-0.7154	-0.2070	0.5718
Main-Disc	0.0332	0.2298	0.9197
Disc-Disc	-0.2597	-0.0962	0.1203
3+ Tour Days			
Most common purpose	6 trips	7 or 8 trips	9+ trips
Escort	0.4941	0.5590	-0.4112
Maintenance	0.9536	1.7246	0.8771
Discretionary	0.3934	0.7472	-1.5273
4 Tour Days			
Most common purpose	8 trips	9 or 10 trips	11+ trips
Escort	-1.5871	-1.1166	-1.2276
Maintenance	-1.5509	-0.3058	-0.4347
Discretionary	-2.2350	-1.4597	-2.3341
5+ Tour Days			
Most common purpose	10 trips	11 or 12 trips	13+ trips
Escort	-2.7629	-1.8918	-2.0541
Maintenance	-2.7438	-2.0412	-1.6233
Discretionary	-4.7339	-3.4704	-4.8063

Table 2.22 Other Day Pattern Group Parameters: Person Types

	Youth	Grade School	Post-Secondary	Worker Full-time	Worker Part-time	Adult Other	Senior
Number of Tours							
1 tour	0	0	0	0	0	0	0
2 tours	-0.6764	-0.4025	0.1243	0	0	0	0
3 tours	-0.4308	-0.5217	0.1243	0	0	0	0
4 tours	-0.4308	-0.5217	0.3580	0	0	0	0
5+ tours	-0.4308	-0.5217	0.3580	0	0	0	0
Number of Trips							
1 tour, 2 trips	0	0	0	0	0	0	0
1 tour, 3 trips	0	-0.2620	-0.1850	0	0.2909	0	0.2481
1 tour, 4+ trips	-0.4711	-0.9492	-0.1850	0	0.2909	0	0.2481
2 tour, 4 trips	0	0	0	0	0	0	0
2 tour, 5-6 trips	0	0	0	0	0.2360	0	0.1769

	Youth	Grade School	Post-Secondary	Worker Full-time	Worker Part-time	Adult Other	Senior
2 tour, 7+ trips	-0.2862	-0.3008	0	0	0.2360	0	0.1769
3+ tour, no extra trip	0	0	0	0	0	0	0
3+ tour, 1-2 extra trip	0	0	-0.4231	0	0.2606	0	0
3+ tour, 3+ extra trip	-0.7162	-0.7902	-0.4231	0	0.2606	0	0
1 tour: Time Period							
Early	-0.9922	-1.2103	0	0.5222	0	0	0
Early Midday	-0.2989	0.5070	0	0	0	0	0
Full Day	0.8291	1.9709	0.6512	0.7185	0	0	-0.6238
Midday	0	0	0	0	0	0	0
Midday Late	0	0.7988	0	0	0	0	-0.3014
Evening	0	0.2316	0.2269	0.3195	0	0	-0.6102
2 tours: Time Period							
Both daytime	0	0	0	0	0	0	0.3449
Both night	0	0	0	0	0	0	-0.4131
Daytime/Night	0	0	0	0	0	0	0
1 tour: Purpose							
Shop	0	0	0	0	0	0	0
Escort	2.1110	2.3369	0.4264	-0.4232	-0.4875	0	-0.5033
Personal Business	-0.3348	-0.5579	0	0	0	0	0.1824
Social	0	0.4953	0	0	0	0	0.1186
Recreation	0.6004	0	0	-0.1579	0	0	0
Eat	0.2075	0.5714	0.3291	0	-0.2812	0	0
2 tours: Purposes							
Esc-Esc	2.8776	2.4924	1.2795	0	0	0	-0.9530
Esc-Main	1.7133	1.9033	0.7985	0	0	0	0
Esc-Disc	2.3211	2.9882	0.6407	0	-0.4492	0	0
Main-Disc	0	0.5201	0	0	0	0	0.1837
Disc-Disc	0	0.8569	0	0	0	0	0
Main-Main	0	0	0	0	0	0	0
3+ Tours: Purpose							
Esc	1.9736	2.2668	0.8907	-0.8152	-0.4751	0	-0.7915
Disc	0	0	0	0	0	0	0
Main	0	0	0	0	0	0	0

Table 2.23 Other Day Pattern Group Parameters: Person Properties

	1 Person Household	Work at Home	Worker with Child	Nonworking Adult with Child	Child in HH with NWA	Age of Child	Age of Senior
Number of Tours							
1 tour	0	0	0	0	0	0	0
2 tours	0	0	0	0	0	0	-0.0294
3 tours	0	0	0.4397	0.4391	0	0	-0.0243
4 tours	0	0	0.9560	0.7682	0	-0.1020	-0.0985
5+ tours	0	0	1.4353	1.3035	0	-0.1020	-0.0777
Number of Trips							
1 tour, 2 trips	0	0	0	0	0	0	0
1 tour, 3 trips	0.3035	0	0	0	0	0	-0.0149
1 tour, 4+ trips	0.4530	0	0	0	0	0	-0.0149
2 tour, 4 trips	0	0	0	0	0	0	0
2 tour, 5-6 trips	0.4086	0	0	0	0	0	-0.0151
2 tour, 7+ trips	0.6086	0	0	0	0	0	-0.0151
3+ tour, no extra trip	0	0	0	0	0	0	0
3+ tour, 1-2 extra trip	0.3044	0	0	0	0	0	0
3+ tour, 3+ extra trip	0.3044	0	0	0	0	0	0
1 Tour: Time Period							
Early	0	0	0.3418	0	0	0	-0.0266
Early Midday	0	-0.4492	0.3158	0	0	0	0
Full Day	-0.1366	-1.0880	0	0	-0.8795	0	0
Midday	0	0	0	0	0	0	0
Midday Late	0	0	0.1399	-0.2833	-0.5577	0	0
Evening	-0.3444	0.3034	0.2120	0	0	0	0
2 Tours: Time Period							
Both daytime	0	0	0	0.4329	0.5706	-0.1556	0
Both night	0	0	0	0	0	0	0
Daytime/Night	0	0	0	0	0	0	0
1 Tour: Purpose							
Shop	0	0	0	0	0	0	0
Escort	-0.7081	0.6854	0.9760	0.9209	-0.2641	0	0
Personal Business	0	0	0	0	0	0.0799	0

	1 Person Household	Work at Home	Worker with Child	Nonworking Adult with Child	Child in HH with NWA	Age of Child	Age of Senior
Social	0	0	0	0	0	0.0408	0
Recreation	0	0	0	0	0	0.0822	0.0087
Eat	0.2200	-0.4235	-0.2550	-0.7034	0	0	0
2 Tours: Purposes							
Esc-Esc	-1.8351	0	2.0961	2.0253	-0.2529	0	0
Esc-Main	-0.6232	0	1.6079	1.4032	0	0	0
Esc-Disc	-0.6232	0	1.6079	1.4032	0	0	0
Main-Disc	0	0	0	0	0	0	0
Disc-Disc	0	0	0	0	0	0	0
Main-Main	0	0	0	0	0	0	0
3+ Tours: Purpose							
Esc	-0.8905	0	2.0621	1.6506	0	-0.1254	0
Disc	0.6520	0	0	0	0	0.0840	0
Main	0	0	0	0	0	0	0

Table 2.24 Other Day Pattern Group Parameters: Household Income

	Inc <10K	10-25K	25-35K	35-50K	50-75K	75-100K	100K+
Number of Tours							
1 tour	0	0	0	0	0	0	0
2 tours	-0.5237	-0.0370	-0.0546	0	0	0	0
3 tours	-1.1047	-1.0296	-0.5475	-0.4496	-0.1546	0	0
4 tours	-1.1500	-1.1742	-0.6209	-0.4821	-0.2063	0	0
5+ tours	-1.6050	-1.1556	-0.7092	-0.7764	-0.3074	0	0
Number of Trips							
1 tour, 2 trips	0	0	0	0	0	0	0
1 tour, 3 trips	-0.2529	-0.2353	-0.1467	0	0	0	0
1 tour, 4+ trips	-0.2529	-0.2353	-0.1467	0	0	0	0
2 tour, 4 trips	0	0	0	0	0	0	0
2 tour, 5-6 trips	0	-0.4024	-0.2160	0	0	0	0
2 tour, 7+ trips	0	-0.4024	-0.2160	0	0	0	0
3+ tour, no extra trip	0	0	0	0	0	0	0

	Inc <10K	10-25K	25-35K	35-50K	50-75K	75-100K	100K+
3+ tour, 1-2 extra trip	0	0	-0.1529	-0.1413	0	0	0.2839
3+ tour, 3+ extra trip	0	0	-0.1529	-0.1413	0	0	0.2839
1 Tour: Time Period							
Early	0	0	0	0	0	0	0
Early Midday	0	0	0	0	0	0	0
Full Day	0	0	0	0	0	0	0
Midday	0	0	0	0	0	0	0
Midday Late	0	0	0	0	0	0	0
Evening	0	0	0	0	0	0	0
2 Tours: Time Period							
Both daytime	0	0	0	0	0	0	0
Both night	0	0	0	0	0	0	0
Daytime/Night	0	0	0	0	0	0	0
1 Tour: Purpose							
Shop	0	0	0	0	0	0	0
Escort	0	0	0	0	0	0	0
Personal Business	0	0	0	0	0	0	0
Social	0	0	0	0	0	0	0
Recreation	-0.6156	-0.6156	-0.2180	-0.2180	0	0	0
Eat	-0.6152	-0.6152	-0.3137	-0.3137	0	0	0.4096
2 Tours: Purposes							
Esc-Esc	0	0	0	0	0	0	0
Esc-Main	0	0	0	0	0	0	0
Esc-Disc	-0.3444	-0.3444	-0.1392	-0.1392	0	0	0.1863
Main-Disc	-0.3444	-0.3444	-0.1392	-0.1392	0	0	0.1863
Disc-Disc	-0.5951	-0.5951	-0.4543	-0.4543	0	0	0.4947
Main-Main	0	0	0	0	0	0	0
3+ Tours: Purpose							
Esc	0.5554	0.5554	0.4013	0.4013	0.2038	0	-0.2863
Disc	0	0	0	0	0	0	0.1300
Main	0	0	0	0	0	0	0

Table 2.25 Other Day Pattern Group Parameters: Transportation Properties

	Insufficient Cars	No Cars	Home Other Accessibility
Number of Tours			
1 tour	0	0	0
2 tours	0	-0.3493	0.0269
3 tours	0	-0.3493	0.0086
4 tours	0	-0.3493	0.0867
5+ tours	0	-0.3493	0.0910
Number of Trips			
1 tour, 2 trips	0	0	0
1 tour, 3 trips	0	-0.2925	-0.1013
1 tour, 4+ trips	0	-0.2925	-0.2252
2 tour, 4 trips	0	0	0
2 tour, 5-6 trips	0	-0.2667	-0.0849
2 tour, 7+ trips	0	-0.2667	-0.1916
3+ tour, no extra trip	0	0	0
3+ tour, 1-2 extra trip	0	-0.6648	-0.0492
3+ tour, 3+ extra trip	0	-0.6648	-0.0492
1 Tour: Time Period			
Early	0	0	0
Early Midday	0	0	0
Full Day	0	0	0
Midday	0	0	0
Midday Late	0	0	0
Evening	0	0	0
2 Tours: Time Period			
Both daytime	0	0	0
Both night	0	0	0
Daytime/Night	0	0	0
1 Tour: Purpose			
Shop	0	0	0
Escort	-0.1371	-0.6510	0
Personal Business	0	0	0
Social	0	0	0

	Insufficient Cars	No Cars	Home Other Accessibility
Recreation	0	0	0
Eat	0	0	0
2 Tours: Purposes			
Esc-Esc	-0.2023	-0.4970	0
Esc-Main	-0.2023	-0.4970	0
Esc-Disc	-0.2023	-0.4970	0
Main-Disc	0	0	0
Disc-Disc	0	0	0
Main-Main	0	0	0
3+ Tours: Purpose			
Esc	-0.2103	-0.7676	0
Disc	-0.5060	-0.8845	0
Main	0	0	0

The key model responses for each of the demographic, socioeconomic, or transportation properties in the parameter set can be summarized as follows:

- **Adult Other.** These are nonworking, nonstudent adults aged 18 to 64, and are the reference group of people for the utility functions; the other 6-person types can best be understood as being relatively more or less likely to choose day pattern groups, as compared with these adult others.
- **Youth.** Preschool children, primarily under 6, the propensity to travel is much lower, especially in terms of the number of tours. There is an additional preference for full day tours, and a reduction in utility for morning travel. This may represent accompanying a caretaking parent all day; the parameters for escort purpose tours are very high across the board.
- **Grade school**. These students are generally similar to Youths in terms of utility; reduced utility for tours and trips, and a strong focus on escort travel. The time of day parameters are somewhat different; there is a stronger increase in full day travel, as well as the alternatives with later travel.
- **Post-secondary.** Post-secondary students show a notable increase in the number of tours, although this is somewhat offset by a reduction in the utility for the more complex numbers of trips, leading to busy days with more home-based travel than nonhome-based. They show an increased propensity for full day and evening travel, and while their tour purpose parameters increase the utility for escort tours, the parameters are much smaller than those for the previous two groups of children.

- **Full-time workers.** Very similar to Adult Others, with relatively few parameters. Some increase in travel early and late in the day, and a reduction in the utility for escort purposes, although this is more reflective of workers without children.
- **Part-time workers.** Strong similarities to Adult Others, especially temporally, and to full-time workers with respect to reduced escort behavior. These people have an increase in tour complexity, with the utility for extra trips higher across all tours.
- **Seniors.** Also exhibit an increase in tour complexity; this trip-chaining behavior may reflect greater flexibility in their lifestyles. (There is a countervailing set of parameters that use age for seniors that offsets this effect for older seniors.) There is a reduction for escort purposes, and a clear aversion to evening travel.
- **One person households.** Applying to persons living alone, these parameters have two main effects; firstly, an increase in the utility for more complex tours with additional trips. This likely reflects both additional flexibility, as well as no need to return home to meet up with other household members; an Adult Other in a larger household may do shopping in the day, and then return home to go out for dinner with the rest of the family, while if the person is single, they can go straight from the shop to the restaurant. Additionally, there is a strong reduction in the utility of escort travel, which makes sense given no other people in the household to escort.
- **Work at home.** These parameters apply to workers who have chosen to work at home as part of the Long Term Decision module. The effects are modest, but indicate reduced utility for full day travel and dining out, and additional utility for an escort tour.
- **Workers with children**. These parameters apply to workers who have a child (under 18) in the household. There is a strong increase in the total number of tours, which may represent additional demands to serve children in the household, as well as a very strong increase in the utility for escort behavior; more than enough to "override" the reduction in utility for workers overall. There is also an increase in the utility of earlier or later tours, perhaps indicating either before-school or after-school interaction with their children.
- **Nonworking adults with children**. These parameters apply to Adult Others and seniors in households with children under 18. The effects are generally similar to that for workers; strong increases in the number of tours and in the utility for escort tours. There are fewer changes in the time period parameters, although there is an increase in daytime travel.
- **Children with nonworking adults**. These parameters are the inverse of the above, in that they apply to the children under 18 in households with an Adult Other or Senior. There is a limited effect, with a reduction in the utility

of a full day tour, which may indicate that some of the full day tours are a proxy for daycare. There is similarly a reduction in escort, indicating that perhaps in households without nonworking adults, children do more "tagging along" as a parent runs errands on their day off work.

- **Age of child**. These parameters are multiplied by the age of the child (capped at 18). There is a reduction in the utility for days with a high number of tours as children age; this may be because older children are supposed to be at school, so when they are not performing a school activity, it is often because they are sick or have an appointment of some sort, which implies reduced travel. Older children are also less likely to make two tours both during the day, and more likely to have a tour for personal business (such as a doctor's appointment), or a social/recreation purpose. This is also true for more complex days, as discretionary travel increases, but the utility for escort reduces greatly – older children are less likely to be dragged along by their parents on a complex day; they can stay at home or travel for their own purposes instead.
- **Age of senior**. These parameters are multiplied by the age of the senior over 65 (i.e., for a 72-year old, these parameters are all multiplied by 72-65 = 7). This provides for a strong reduction in travel as seniors age, both in terms of number of tours and the number of trips on those tours. There are also small increases in the utility of a recreation tour, and decrease in the utility of a one-tour day being an Early day, however, these are much smaller than the effects in terms of the total amount of travel.
- **Income**. The effects of income are consistent across the seven levels of income, with utilities for alternatives either increasing or decreasing as income increases. The number of tours is strongly dependent on income, with lower income households experiencing very large reductions in the utilities of the day pattern groups with large numbers of tours. There is no comparable increase at the high end of the income scale, implying that low incomes suppress travel rather than high incomes provide increased travel. A similar pattern is seen in a reduction in the utility of more complex tours with more trips; the lowest income households did not have a statistically significant parameter producing this effect for days with large numbers of tours, but they are much less likely to select those days in the first place.

  In terms of purposes, a clear trend is visible where lower income household members have a reduced utility in travel for more discretionary purposes; for recreation or eating in a one-tour day, and for all of the discretionary purposes in two-tour days. For three-plus-tour day pattern groups, these low income households were more likely to select escort days; serving household members may be the strongest cause of travel-heavy days. In terms of purpose, there is a countervailing effect amongst high income households increasing their propensity for leisure travel.

- **Auto ownership.** There are two sets of parameters responding to auto ownership; insufficient cars and no cars at all. They both have similar responses in terms of tour purposes (with insufficient cars having a smaller effect than no cars); a reduction in escort travel across the board, and a reduction in discretionary travel for day pattern groups with three or more tours. It is reasonable that households with fewer cars are less able to escort each other, and that if they do have a busy day with many tours, that it will primarily be for maintenance purposes rather than more discretionary ones. For households without cars entirely, there is also a significant reduction in the utility of making several tours, and in making additional stops on the tours that are made. Travelers without cars often take public transit, which often provides much better service for commuting, rather than making several stops at different locations.
- **Other accessibility.** This is the logsum of the simplified Other model (described below) to all destinations, from the home zone. This is a multimodal accessibility that represents all other tour destinations; the larger the value, the more accessible a zone is. (In the base year, this range is roughly from 3.5 for the least accessible zone to 9.3 for the most accessible.) The parameters that are multiplied by this alternative have two effects; as accessibility rises, the utility of making more tours increases, while the utility of making more stops on a given number of tours decreases. Households in low accessibility areas (like rural households) will tend to make fewer tours, with more stops; households in high accessibility areas will tend to make more tours, with fewer stops. This is the same tradeoff seen in the Work Day Pattern Group Choice model.

  The other accessibility is a logsum of a destination choice model; this destination choice model was estimated across all other tours for the purpose of creating a single measure of Other tour accessibility for the purpose of Day Pattern Group choice (it appears in both Other and School models). When the SDPTM simulates the actual Other tours, it uses more complex models, with a fully specified tour mode choice model presented in Section 3 of this document, and a series of purpose-specific destination choice models and trip mode choice models described in the SDPTM Part 3 report. The destination choice includes a composite size term for each zone, as well as a travel cost logsum representing a simplified mode choice model.

  The size term includes several different attractors, and represents all other travel. Of primary importance is retail and leisure/hospitality employment, which is consistent with the destination choice models for several Other purposes.

  This logsum is weighted piecewise in the destination choice model; the primary effect is to create more significance to the first portion of the logsum; in other words, a small difference between travel costs is more important if the destination is close by; the difference between traveling 5 miles and 10 miles feel much greater than that of traveling 55 miles versus 60 miles.

The piecewise break points are at -1 and -3, which correspond roughly with 7.5 miles and 25 miles, depending on transit service and travel conditions. The parameters of this overall simplified destination choice are listed in Table 2.26.

The simplified mode choice model was also estimated across all other tours, combining the modes into three: auto (SOV, HOV2, HOV3+); transit (WAT, DAT); and active (Walk, Bike). The model uses the travel conditions of a midday outbound and return tour. The parameters for this model are also listed in Table 2.26.

Table 2.26 Simplified Other Destination and Mode Choice Function for Day Pattern Group Model

Aspect	Parameter	Value
Overall destination choice	Size term	0.8803
	Mode choice logsum, portion to -1	4.8826
	Mode choice logsum, portion between -1 and -3	0.4463
	Mode choice logsum, portion beyond -3	1.2421
Size term	Total employment	1.0
	Total households	3.99
	Retail employment	11.65
	Leisure and Hospitality employment	14.02
Mode choice: auto	Money cost	-0.1326
	SOV travel time	-0.0232
Mode choice: transit	Alternative-specific constant	-0.2136
	Money cost	-0.1326
	Walk Access Transit travel time, first 180 mins.	-0.0200
	Walk Access Transit travel time, over 180 mins.	-0.0070
Mode choice: active	Alternative-specific constant	0.4796
	Walk time, first 120 mins.	-0.0389
	Walk time, over 120 mins.	-0.0030

2.5 Day Pattern Choice Model

For each person processed by the Day Pattern model, the first step is the selection of a Day Role, which can be one of five options (Work, School, Both, Other, None) for day patterns as described in Section 2.1 of this document. If the day role selected is Work, School or Other, then a second Day Pattern Group model chooses a day pattern group, as described in Sections 2.2 to 2.4 of this report. If the day role selected is Both (a small proportion of days) or None, then there is no day pattern group choice; effectively, there is only one day pattern group for each of these alternatives.

At this point, the person has been assigned a day pattern group, but a specific day pattern needs to be chosen. The day pattern groups have been selected to group very similar patterns together; indeed, several of the most common groups have only one possible pattern (such as a 1 tour Other day, with a 2-trip tour, Shop purpose, and midday time period; the only day pattern that firs this alternative is home – midday travel – shop – midday travel – home). Of course, the None pattern group contains only the day pattern of no travel.

Because these groups have similar patterns in terms of the amount of travel, purpose of travel, structure in tours and trips, and time of travel, the day patterns are tightly delineated. The day pattern choice model, then, simply selects a day pattern from the chosen group of day patterns, based on observed frequency.

Because all of the day patterns that the model selects from have been observed in the survey, there are several benefits; it by definition removes impossible or unreasonable patterns from the decision. Further, the correlations that occur in the real world are maintained in the model. For instance, in Other days with two tours, the Main-Disc option describes a day with a maintenance tour and a discretionary tour, without specifying the order. However, the observed data shows that 62 percent of the time, the maintenance tour occurs first, with discretionary afterward; the reverse only occurs 38 percent of the time.

Once the day pattern is chosen, the model processes each tour in the day pattern in order. If a tour is a work or school tour, the primary destination is assumed to be the work or school location chosen in the Long-Term Decision modules, and the next decision is the tour mode choice. If the tour is an other tour, then the mode choice decision is made before a destination is chosen.

3.0 Main Tour Mode Models

This section describes the development and estimation of tour mode choice models for the SDPTM.

The tour-based mode choice models differ from traditional trip-based mode choice models in that there are two different levels of forecasting models: tour mode choice models (upper-level choice) and trip mode choice models (lower-level choice on the basis of upper-level choice). The tour mode choice models determine the "main tour mode"; whereas, the trip model choice models determine the mode for each individual trip made on that tour on the basis of the mode chosen for the tour.

Full logit tour mode choice models are applied to forecast the "main tour mode," which is the overall mode from the tour origin (usually home) to the primary destination, and back to the origin, among available mode alternatives. Note that while the simplified work and school tour mode choice models described in Part 1 of this document (which are used to provide logsums for work and school destination choice) use an assumed time period to get travel times for all workers and students, the mode choice models described in this section use the specific outbound and return time periods of the tour being modeled.

The SDPTM considers eight travel modes (although not all modes are available for some person/purpose combinations):

1. Single Occupant Auto (SOV) (not available for persons with no driving license or from a zero-auto owning household);
2. High Occupant Auto with 2-persons in the auto (HOV2);
3. High Occupant Auto with 3+persons in the auto (HOV3):
4. Walk Access Local Transit (bus, light rail, heavy rail) (not available for origin-destination pairs with no transit service);
5. Drive Access Local Transit (access to or egress from a rail station is by auto) (not available for origin-destination pairs with no transit service);
6. Walk (not available for a round trip tour distance > 10 miles);
7. Bicycle; and
8. School Bus (only available for Grade School Tours).

Three separate main tour mode models have been estimated, for three tour purposes: Work, School and Other.

The main tour mode choice models were originally estimated by the application of the ALOGIT package to observed mode choice behavior from the combined California travel surveys as part of the CSTDM model development process, and further calibrated as part of the CSTDM 2.0 work. A very brief overview of the underlying theory underpinning these models is given below.

The overall postulation in disaggregate behaviour modeling is that the probability of an individual choosing a given alternative is a function of the socioeconomic characteristics of the individual and the relative attractiveness of the alternative. The attractiveness of alternatives is represented using the concept of utility, which is a numeric measure of the attractiveness an individual associates with an alternative. This derivation of a utility value from the attributes of the alternative by the individual is represented using a utility function, as follows:

U(a,i) = F { X(a), C(i), K }

where:

U(a,i) = Utility individual i associates with alternative a

X(a) = Vector of numeric measures of attributes of alternative a

C(i) = Vector of numeric measures of characteristics of individual i

K = Vector of utility function parameters.

The individual's choice behaviour is viewed as an exercise in maximizing this utility, either consciously or unconsciously, by selecting the alternative that provides the bundle of attributes with the greatest utility – the concept of "rational choice behaviour."

The form of a single-level logit model of choice behaviour amongst a set of alternatives is:

$$P(j^*) = \frac{e^{U_{j^*}}}{\sum_{j \in J} e^{U_j}}$$

where:

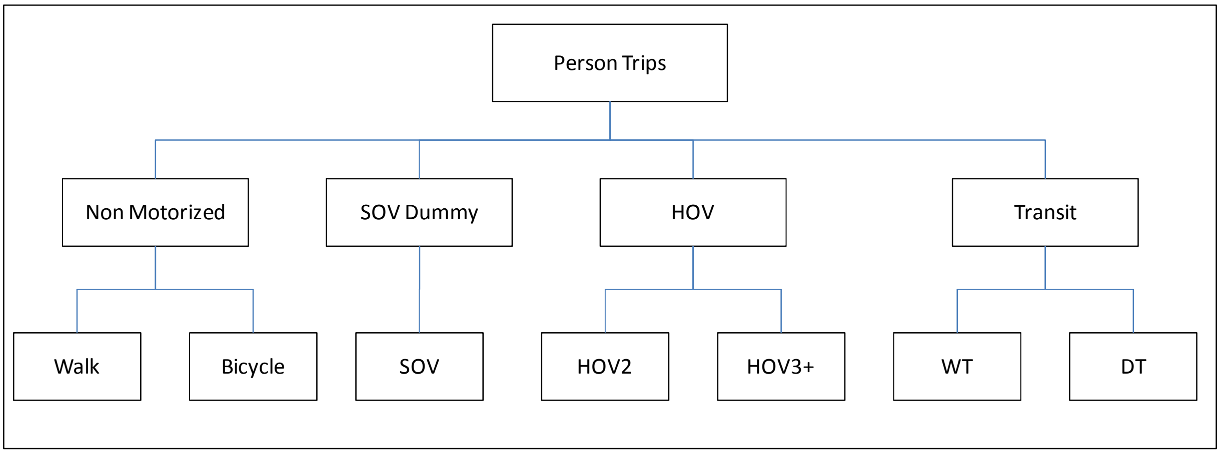
P(j*) = Probability choosing alternative j* amongst set of alternatives J

U_j = Utility of alternative j*

U_j = Utility of every alternative j in set J

In the CSTDM 2.0 main tour mode models a "nested logit" model approach is used. Figure 3.1 illustrates the choice structure for the Work model.

Figure 3.1 Example of Nested Logit Model Structure: Main Tour Mode Model: Work



For a given TAZ-TAZ and time period combination of tour outbound and return trips, the probability of choosing a mode between the 4 options, in the "upper level" is calculated:

- Nonmotorized;
- SOV (dummy);
- HOV; and
- Transit.

Once the probability at the "upper level" has been determined, the further probabilities are calculated for the choices at the "lower level":

- For nonmotorized modes, the choice between walk and bicycle;
- For SOV, there are no suboptions so the choice probability is 100 percent SOV;
- For HOV, the choice between HOV2 and HOV3; and
- For Transit, the choice between Walk Access Transit (WT) and Drive Access Transit (DT).

The analytic form of the nested logit formulation, for a set of alternatives B in the lower level, and a set of alternatives C in the higher level, is:

- **Lower level**

$$P[b*|B,i] = \frac{\exp(U(b*,i))}{\sum_{b \in B} \exp(U(b,i))}$$

- **Higher level**

$$P[c,i] = \frac{\exp(\lambda \cdot U(c,i))}{\sum_{b \in B} \exp(\lambda \cdot CU(B,i))}$$

$$CU(B,i) = \lambda \cdot \log\{\sum_{b \in B} \exp(\cdot U(b,i))\}$$

where:

b = Index representing alternative in set B

c = Index representing alternative in set C

P[b* | B,i] = Probability that alternative b* is selected given B set chosen

P[c,i] = Probability that alternative c is selected

CU(B,i) = Composite utility for the B set alternative

λ = Nesting parameter for lower level

The composite utility term represents the utility associated with the 'B' alternative as a composite of the utility values for each of the b alternatives in combination.

In order for the model's cross-elasticities for alternatives in the different sub-sets to be sensible, the nesting parameter dispersion parameter λ must have a value within the range 0 and 1.0. This ensures that there will be greater shifts in choice probability between alternatives that share more attributes (and error terms) and are therefore more similar.

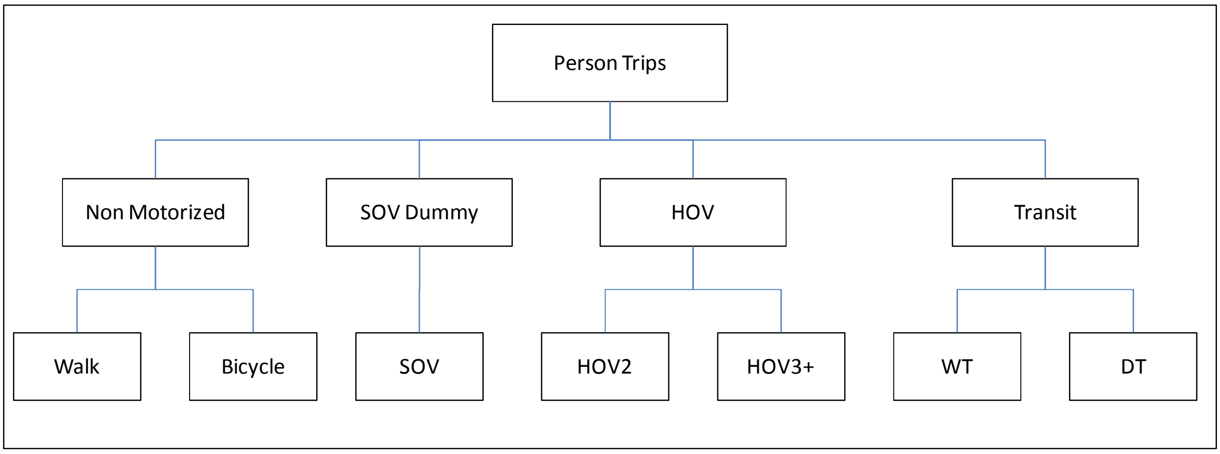
In the CSTDM 2.0 disaggregate application of these models, a "Monte-Carlo" approach is used to sample from the calculated probability distributions, to allocate a specific mode to each individual.

The final main tour mode models used in the SDPTM, after calibration adjustments, are described in the following sections.

3.1 WORK MAIN TOUR MODE MODEL

The nesting structure for this model is given in Figure 3.2. The utility parameter values for each mode for the Work Main Tour Mode are given in Table 3.1 below.

Figure 3.2 Nested Logit Model Structure for Main Tour Mode Model: Work



Note: WT = Walk Access Transit; DT = Drive Access Transit.

Table 3.1 Work Main Tour Mode Parameters

Parameters	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)	-0.07541
Auto In-vehicle time, HH income < 25K (min)	-0.01007
Auto In-vehicle time, HH income 25K-100K (min)	-0.02261
Auto In-vehicle time, HH income >= 100K (min)	-0.03211
Transit In-vehicle time, HH income <100K (min)	-0.00577
Transit In-vehicle time, HH income >=100K (min)	-0.00938
Walk/bicycle time less than 20 minutes (min)	-0.09428
Walk/bicycle time between 20 minutes and 70 minutes (min)	-0.05246
Walk/bicycle time more than 70 minutes (min)	-0.03497
SOV	
Constant	0.63640
MTC additional constant	-1.2922
HH income < 25K	-0.31976
HH income 25K-50K	-0.17660
Office worker (workplace population + employment density <20000)	0.32962
Office worker (workplace population + employment density >=20000)	-0.39352
Blue collar worker	0.29243

Parameters	Parameter Value
HOV2	
Constant	-5.16500
MTC additional constant	-0.67570
No Autos in HH	5.61689
Autos in HH > 0 but < drivers	1.78267
One person HH	-1.35019
Age 40-50	-0.25500
Age > 50	-0.41308
Nonwork adults (including age 65+)	1.16879
Number of outbound stops	0.09333
Departure in PM peak (3 PM – 7 PM)	0.41708
HOV3+	
Constant	-6.83881
MTC additional constant	-1.04100
No Autos in HH	6.67298
Autos in HH > 0 but < drivers	1.93068
One person HH	-1.86484
Two person HH	-0.73114
Age 40-50	-0.58760
Age > 50	-1.06107
Nonworking adults(including 65+)	1.16879
Number of outbound stops	0.09333
Departure in PM peak (3 PM – 7 PM)	0.41708
Walk Access Transit	
Constant	-7.26720
MTC additional constant	0.89970
No Autos in HH	7.54636
Autos in HH > 0 but < drivers	2.56427
HH income < 25K	0.67749
HH income 25K-50K	0.25346
SQRT of origin population and employment density	0.00793
SQRT of destination population and employment density	0.00544
Departure in PM peak (3 PM – 7 PM)	-1.12495

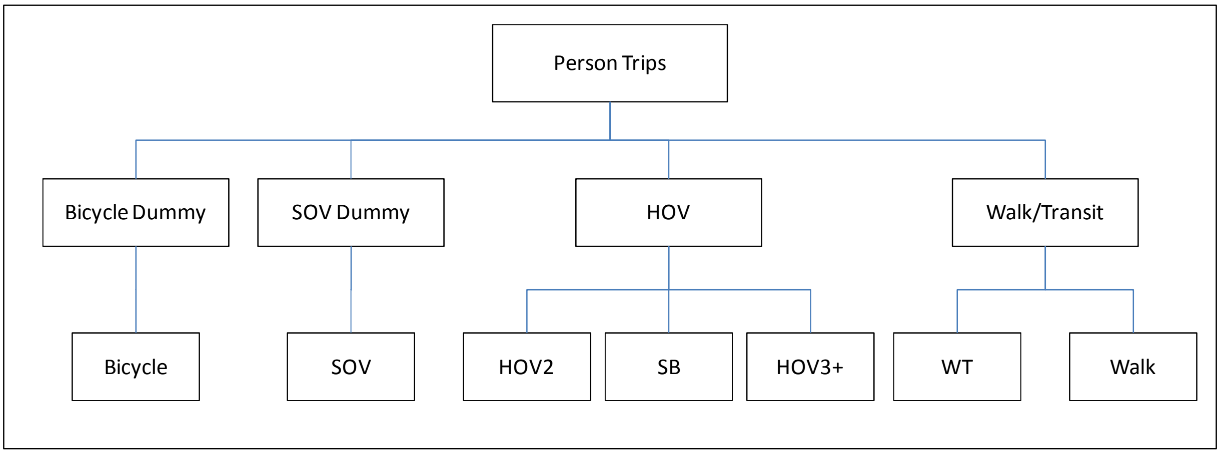
Parameters	Parameter Value
Number of outbound stops	-0.24644
Number of return stops	-0.43816
Drive Access Transit	
Constant	-4.84591
MTC additional constant	0.72450
No Autos in HH	5.83874
Autos in HH > 0 but < drivers	1.86501
SQRT of origin population and employment density	-0.00854
SQRT of destination population and employment density	0.00544
Departure in PM peak (3 PM – 7 PM)	-1.12495
Number of outbound stops	-0.24644
Number of return stops	-0.43816
Walk	
Constant	-1.55255
No Autos in HH	6.54141
Autos in HH > 0 but < drivers	1.84915
SQRT of origin population and employment density	0.00999
Number of outbound stops	-0.80019
Number of return stops	-1.44065
Bicycle	
Constant	-5.03845
MTC additional constant	0.12670
No Autos in HH	6.54141
Autos in HH > 0 but < drivers	1.84915
SQRT of origin population and employment density	0.00440
Number of outbound stops	-0.76698
Number of return stops	-0.74709
Age 60+	-1.64800
Male	1.73900
Nesting Parameters	
All Modes	0.73077

In the model, separate parameters are specified for walk/bicycle travel time in three time bands – less than 20 minutes, 20 to 70 minutes and greater than 70 minutes.

3.2 School Main Tour Mode Models

Two school main tour mode models have been developed – one for Grade School Students; and one for Post-Secondary Education Students. The nesting structure for the Grade School model is shown in Figure 3.4.

Figure 3.3 Nested Logit Model Structure for Main Tour Mode Model: Grade School



Note: SB = School Bus; WT = Walk Access Transit; DT = Drive Access Transit.

The utility parameter values for each mode for the Grade School Main Tour Mode model are given in Table 3.2.

Table 3.2 Grade School Student Main Tour Mode Parameters

Parameter	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)[a]	-0.06961
Auto In-vehicle time (min)	-0.00696
Transit In-vehicle time (min)	-0.00302
Walk time (min)	-0.00170
Bike time (min)	-0.01342
SOV	
Constant – with driving license	4.71856
HH income < 25K	-1.84133

Parameter	Parameter Value
HH income 25K-50K	-1.54397
HH income 50K-100K	-0.67127
Escort stop in a tour	1.85171
HOV2	
Constant – with driving license	5.64276
Constant – without driving license, grade K-8	3.17311
Constant – without driving license, grade 9-12	3.17311
No Autos in HH	-1.91005
Autos in HH > 0 but < drivers	3.12603
HH income 25K-50K	0.44073
HH income 50K-100K	1.38206
HH income > 100K	2.12184
Age	-0.52890
Age square	0.01873
Number of outbound stops in a tour	0.79469
HOV3+	
Constant – with driving license	4.47069
Constant – without driving license, grade K-8	3.21454
Constant – without driving license, grade 9-12	3.21454
No Autos in HH	-1.61884
Autos in HH > 0 but < drivers	3.10644
HH income 25K-50K	0.44073
HH income 50K-100K	1.38206
HH income > 100K	2.12184
Age	-0.52890
Age square	0.01873
Number of outbound stops in a tour	0.79469
School Bus	
Constant – with driving license	0.75927
Constant – without driving license, grade K-8	0.42027
Constant – without driving license, grade 9-12	0.42027
No Autos in HH	0.23641
Autos in HH > 0 but < drivers	2.96046

Parameter	Parameter Value
Age square	-0.00237
SQRT of school location population and employment density	-0.01878
Departure in AM peak (6 AM – 10 AM)	1.52497
Walk Access Transit	
Constant – with driving license	-4.19403
Constant – without driving license, grade K-8	--4.26782
Constant – without driving license, grade 9-12	-4.26782
No Autos in HH	1.82569
Autos in HH > 0 but < drivers	3.54018
Age square	0.01106
SQRT of destination population and employment density	0.00640
Additional Transit Calibration Constant for Density functions	-5.1000
Ln (population density persons/sq.mi in 10-mile buffer radius)	0.1350
Ln (employment density persons/sq.mi in 2-mile buffer radius)	0.4750
Walk	
Constant – with driving license	-0.80230
Constant – without driving license, grade K-8	--0.96080
Constant – without driving license, grade 9-12	-0.96080
Autos in HH > 0 but < drivers	3.09037
HH income <25K	0.59793
HH income 25K-50K	0.30990
SQRT of origin population and employment density	0.00886
Number of stops in a tour	-1.19139
Bicycle	
Constant – with driving license	-11.19856
Constant – without driving license, grade K-8	-12.93090
Constant – without driving license, grade 9-12	-2.93090
No Autos in HH	-1.32334
Autos in HH > 0 but < drivers	3.84415
Age	1.30953
Age square	-0.05074
HH income <25K	0.59793
HH income 25K-50K	0.30990

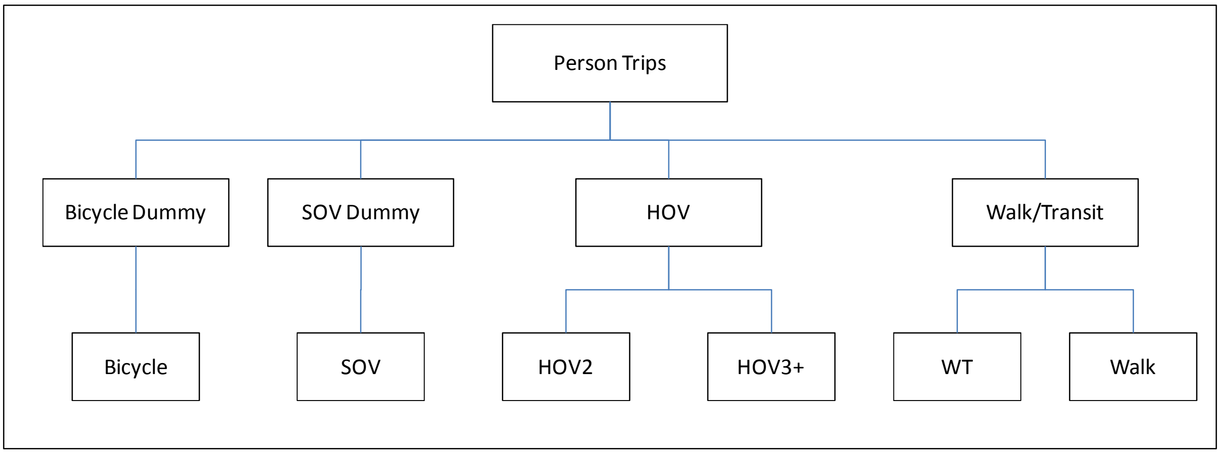
Parameter	Parameter Value
Number of stops in a tour	-1.13997
Male	1.99964
Nesting Parameters	
All Modes	0.61490

[a] Value of time for grade students was set to $6 per hour.

During calibration, additional transit density functions were applied as listed above, based on observed very limited transit usage in low density areas

The nesting structure for the Post-Secondary Education Main Tour Mode model is shown in Figure 3.5.The utility parameter values for each mode for the Post-Secondary Student Main Tour Mode model are given in Table 3.3.

Figure 3.4 Nested Logit Model Structure Main Tour Mode Model: Post-Secondary



Note: SB = WT = Walk Access Transit; DT = Drive Access Transit.

Table 3.3 Post-Secondary Student Main Tour Mode Parameters

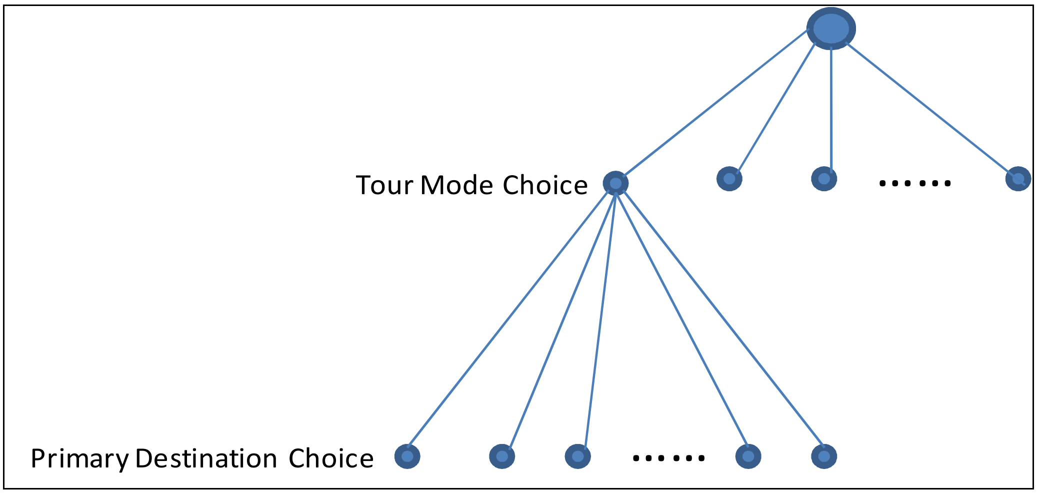
Parameter	Parameter Value
Level of Service	
Cost (Operation fee, parking, toll, fare) ($)	-0.19549
Auto In-vehicle time (min)	-0.02077
Transit In-vehicle time (min)	-0.00603
walk time less than 20 minutes (min)	-0.11959
walk time between 20 minutes and 70 minutes (min)	-0.07140
walk time more than 70 minutes (min)	-0.00434
bicycle time less than 70 minutes (min)	-0.05322
bicycle time more than 70 minutes (min)	-0.02970
SOV	
Constant	0.51020
Autos in HH > 0 but < drivers	-2.30710
HH income < 25K	-1.35189
HH income 25K- 50K	-1.01491
Full or part-time job	0.88143
HOV2	
Constant	-4.49710
No Autos in HH	6.50149
Autos in HH > 0 but < drivers	-0.90679
One person HH	-1.70719
HOV3+	
Constant	-7.11860
No Autos in HH	7.14905
Autos in HH > 0 but < drivers	-0.75085
One person HH	-3.16040
Two person HH	-0.78847
Walk Access Transit	
Constant	-3.27642
No Autos in HH	7.51486
Number of stops in a tour	-0.60919

Parameter	Parameter Value
Walk	
Constant	-1.80503
No Autos in HH	6.33204
Number of stops in a tour	-1.28257
Bicycle	
Constant	-5.77596
No Autos in HH	6.33204
Number of stops in a tour	-0.98434
Male	1.36600
Nesting Parameters	
All Modes	0.69090

3.3 Other Main Tour Mode Model

The Other purpose main tour mode model has a different form and structure than the Work and School tour mode models. For this purpose the tour mode is determined ***before*** the primary destination choice, rather than after destination choice, as illustrated in Figure 3.6.

Figure 3.5 Model structure for "Other" Purpose Main Tour Mode Model



For this model structure, the mode choice is not made for each TAZ-TAZ pair. Instead, the tour mode for each home zone TAZ is determined using mode-specific logsums of generalized travel cost to all available destinations, obtained from the Primary Destination Choice model.

Seven different purposes are considered as part of the "Other Purposes" model:

1. Eat;
2. Recreation (including entertainment) (Rec);
3. Shop;
4. Personal Business (PB);
5. Social (Soc);
6. Escort for persons in households with children (Esc_K); and
7. Escort for persons in households without children (Esc_NK).

From the primary destination choice model, logsums of generalized travel cost to all available destinations from each TAZ are calculated, for each of the 7 purposes, for each of the 7 modes (SOV, HOV2, HOV3, Walk Access Transit, Drive Access Transit, Walk and Bicycle).

For each logsum, the following calculation is made:

$$\mathrm{logsum_i} = \ln\left(\sum_j e^{U_{ij}}\right)$$

where: $U_{ij} = p_c\left(\mathrm{cost}_{ij} + \mathrm{cost}_{ji}\right) + \ln(\mathrm{TotEmp} + \sum_s p_s \mathrm{Size}_s)$

where the costs are composite costs of travel, the Size elements are zonal properties, such as the number of jobs in an industry type, and p_c and p_s are estimated parameters.

The logsums are calculated for the time period pairs, for the outbound and return trips of the tour. Every possible time period pair combination is calculated, keeping the early and late off-peak separate. While the travel times and costs for a tour starting and ending in the early off-peak would be the same as that for one starting in the early and ending in the late off-peak, the parking cost is different. Table 3.4 gives the parameter values for the Other Main Tour Mode model.

During calibration, additional transit density functions were applied as listed above, based on observed very limited transit usage in low density areas. Also, the cost of parking was halved for other tours, as a recognition of both the increased availability of parking in areas typically visited for non-work travel and of the decreased perception in parking costs as shared by a group.

Table 3.4 Other Main Tour Mode Parameters

Parameters	Parameter Value
Destination Accessibility (logsums)	
SOV	0.84879
HOV2	0.69044
HOV3	0.69044
Walk Access Transit	0.21371
Drive Access Transit	0.17387
Walk	0.40981
Bicycle	0.61343
SOV	
Constant – eat	0.51370
Constant – escort	0.88480
Constant – personal business	-0.10980
Constant – recreation	-0.11780
Constant – shopping	0.00620
Constant – social	0.07180
Nonwork adult	-0.18630
Age 16-29	0.56016
Age 40-49	1.09865
Age 50-64	1.61192
Age >64	1.51529
HH income 75K – 100K	0.11048
HH income 100K – 150K	0.12702
HH income > 150K	0.21256
HOV2	
Constant – eat	3.17929
Constant – escort	0.39881
Constant – personal business	1.70031
Constant – recreation	1.56345
Constant – shopping	1.55655
Constant – social	1.20132
No Autos in HH	2.91184
Autos in HH > 0 but < drivers	0.77555
One person HH	-2.21703
Age 40-49	0.29016

Parameters	Parameter Value
Age 50-64	0.54413
Age 65+	0.94721
Departure in PM peak (3 PM – 7 PM)	0.57460
HOV3+	
Constant – eat	3.54152
Constant – escort	-0.52247
Constant – personal business	1.83107
Constant – recreation	1.81592
Constant – shopping	1.58161
Constant – social	2.00567
No Autos in HH	3.33007
Autos in HH > 0 but < drivers	0.65707
One person HH	-3.16195
Two person HH	-1.71050
Child Age 0-5	0.58583
Child age 6-15	0.64340
Age 50-64	-0.33685
Departure in PM peak (3 PM – 7 PM)	0.57460
Walk Access Transit	
Constant – eat	5.59664
Constant – escort	1.25099
Constant – personal business	4.26992
Constant – recreation	4.30225
Constant – shopping	3.90083
Constant – social	3.27902
No Autos in HH	7.92212
Autos in HH > 0 but < drivers	0.72303
HH income < 25K	0.38630
HH income 25K-50K	0.78023
Full-time worker	-1.53704
Child Age 0-5	-1.09244
Child age 6-15	-0.58547
Age 50-64	-0.41698
Age 65+	-0.42619
Number of stops	-0.33842

Parameters	Parameter Value
Additional Transit Calibration Constant for Density functions	-7.8000
Ln (population density persons/sq.mi in 10-mile buffer radius)	0.6450
Ln (employment density persons/sq.mi in 2-mile buffer radius)	0.2450
Drive Access Transit	
Constant – eat	6.30480
Constant – escort	-1.09231
Constant – personal business	3.14253
Constant – recreation	3.86566
Constant – shopping	2.29943
Constant – social	1.66577
No Autos in HH	5.41327
Autos in HH > 0 but < drivers	0.60384
HH income < 25K	0.38630
HH income 25K-50K	0.78023
Full-time worker	-1.53704
Child Age 0-5	-1.09244
Child age 6-15	-0.58547
Age 50-64	-0.41698
Age 65+	-0.42619
Number of stops	-0.33842
Additional Transit Calibration Constant for Density functions	-7.8000
Ln (population density persons/sq.mi in 10-mile buffer radius)	0.6450
Ln (employment density persons/sq.mi in 2-mile buffer radius)	0.2450
Walk	
Constant – eat	4.80542
Constant – escort	2.36830
Constant – personal business	2.21171
Constant – recreation	5.14403
Constant – shopping	3.40622
Constant – social	2.76793
No Autos in HH	5.26817
Autos in HH > 0 but < drivers	1.51802
HH income < 25K	1.35272
HH income 25K-50K	0.60985
SQRT of origin population and employment density	0.01309

Parameters	Parameter Value
Number of stops	-1.46582
Bicycle	
Constant – eat	-0.22316
Constant – escort	-4.51374
Constant – personal business	-3.39535
Constant – recreation	-0.02909
Constant – shopping	-2.81590
Constant – social	-1.32812
Age 6-15	0.40588
Age 16-19	0.44179
Age 40-49	0.46155
Age 65+	-0.71187
No Autos in HH	5.26817
Autos in HH > 0 but < drivers	1.51802
SQRT of origin population and employment density	0.00457
Number of stops	-0.63743
Male	1.04633
Nesting Parameters	
All Modes	0.69168

4.0 Calibration of Day Pattern and Main Tour Mode Models

4.1 DAY PATTERN MODEL

The day pattern models were calibrated in two phases. The first was to calibrate the Day Role model to produce the correct distribution of day roles; the second was to calibrate the Day Pattern Group models jointly to produce the correct distribution of travel activity.

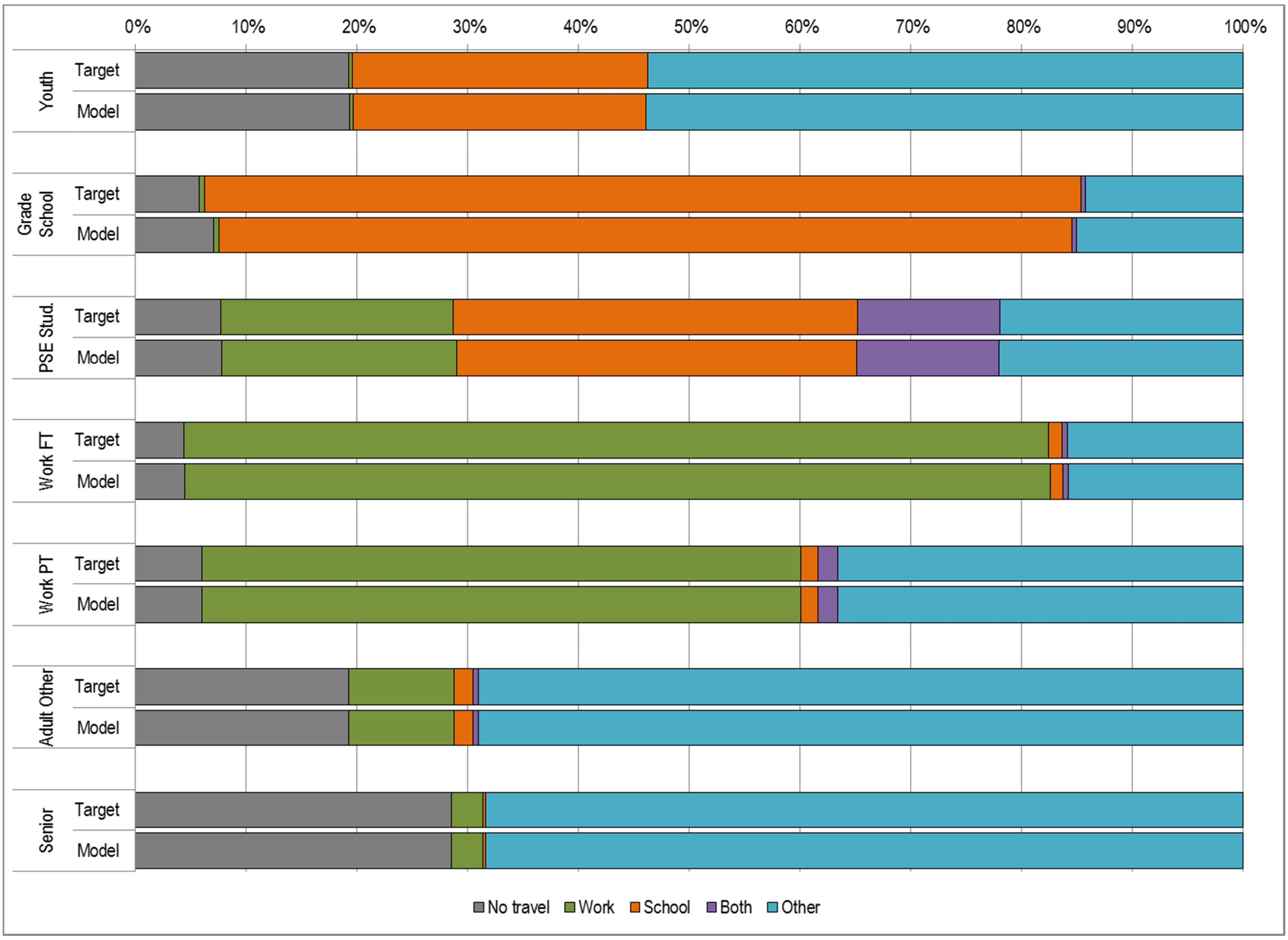
The Day Role calibration data used the observed data for California from the 2012 California Household Travel Survey (CHTS), augmented with the National Household Travel Survey (NHTS), done in 2009. The observed rates of "no travel" from the CHTS were seen to be significantly higher than the rates found in the NHTS overall. Initial SDPTM models calibrated using the observed CHTS no travel rates were seen to produce forecast travel patterns, and in particular vehicle screen-line flows, that were significantly lower than observed vehicle counts. The calibration of the SDPTM model using the NHTS no travel rates gave a much closer fit between model and observed screen-lines. While the "no travel" rates are adjusted to match the NHTS rates, the other day role choice shares are based on the CHTS data.

The Day Pattern calibration used observed tour rates from the CHTS, explicitly scaled up to give an additional 13.5% in trip-making. This increase is consistent with the trip under-reporting found by NuStats, the CHTS Survey implementer, when GPS trip data was compared with trip diary data for the same individual.

Both sets are also divided amongst the seven basic person types used elsewhere in the day pattern model.

The day role model was calibrated by adjusting the alternative-specific constants for each role for each person type to match the shares observed in the survey data. These calibrated constants are the ones reported in Table 2.2. Figure 4.1 shows the calibration results for the Day Role model; the match between target and model is excellent.

Figure 4.1 Day Role Model Calibration



To calibrate the Day Pattern Group Choice Models, the day pattern groups were analyzed in terms of the average number of trips in the day patterns of each group. These groups were assigned to three levels of activity; "simple" day pattern groups, which had fewer than 3.5 trips on average, "moderate" day pattern groups, which had between 3.5 and 6.5 trips on average, and "complex" day pattern groups, which had 6.5 or more trips on average.

CHTS data was used to develop shares of days with each of these three levels of activity, by the seven person types. These shares exclude persons who do not travel. An additional set of calibration parameters were developed for each of these three levels of activity, and each of the three person types. The parameters were added to the utility of choosing all day pattern groups with that specific activity level, across the Work, School and Other day pattern group models. They are thus effectively part of the alternative-specific constants.

The day pattern group model was then calibrated by adjusting these for each role for each activity level to match the shares observed in the survey data. These calibrated constants are the ones reported in Table 4.1 below.

Table 4.1 Day Pattern Group Calibration Parameters

Person Type	Simple Groups (1-3 Trips)	Moderate Groups (4-6 Trips)	Complex Groups (7++ Trips)
Youth	0	0.2605	0.9272
Grade School	0	-0.5855	-1.2064
Post-Secondary	0	-0.1827	0.7320
Worker Full-time	0	0.2244	0.6648
Worker Part-time	0	0.3840	0.8581
Adult Other	0	0.1255	0.5709
Senior	0	0.2432	0.5372

Figure 4.2 shows the calibration results for the Day Pattern Group models; the match between target and model is excellent.

Figure 4.2 Day Pattern Group Choice Model Calibration

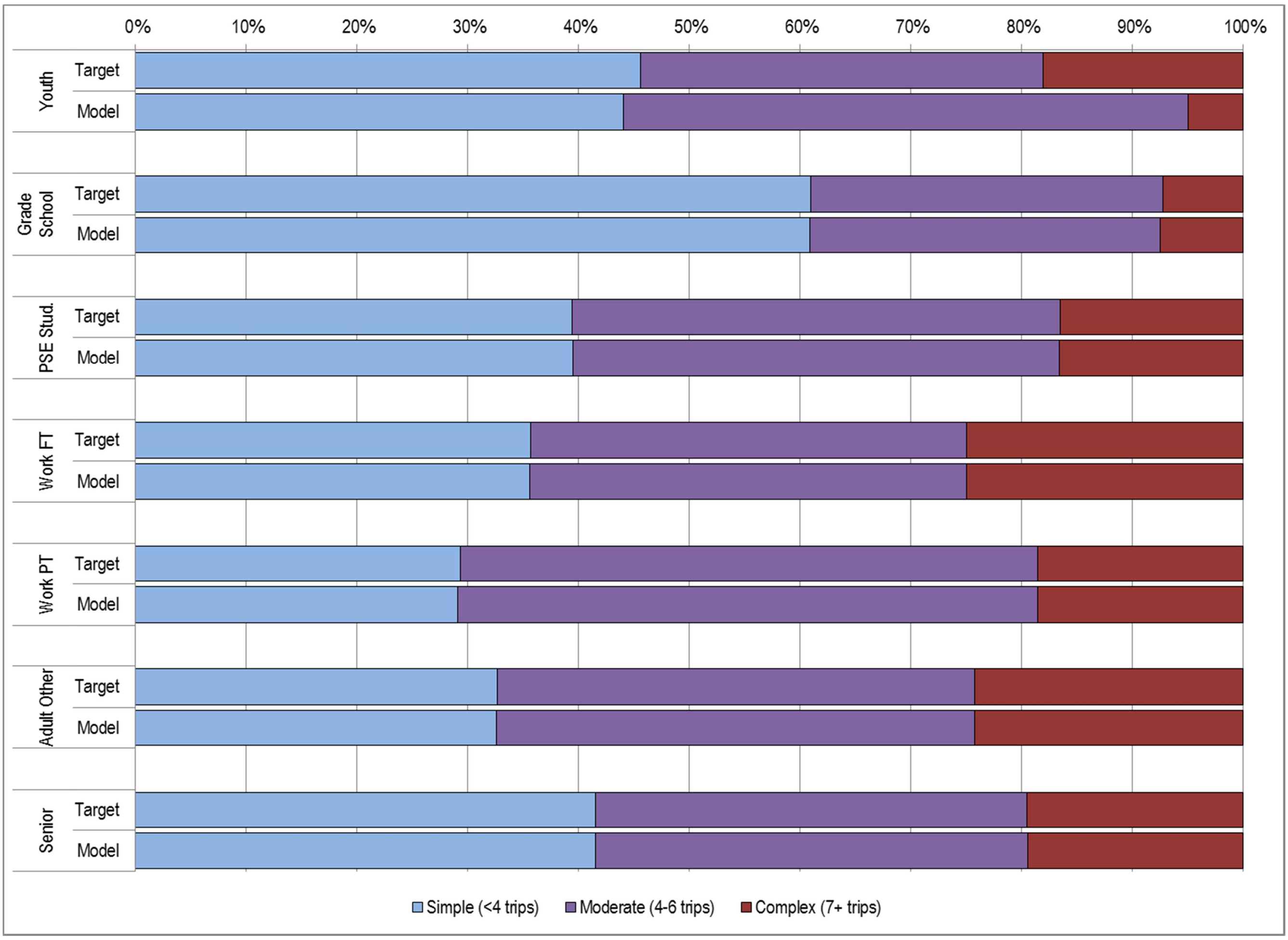


Table 4.2 lists the average trips per person from the CHTS and the calibrated Day Pattern model. The model performs fairly well.

Table 4.2 Day Pattern Group Calibration Parameters

Group	Trips per Person CHTS	Trips per Person SDPTM	Percent Difference
Youth	3.55	3.42	-3.6%
Grade School	3.38	3.37	-0.2%
Post-Secondary	4.05	4.04	-0.2%
Worker Full-time	4.29	4.10	-4.3%
Worker Part-time	4.88	4.61	-5.5%
Adult Other	4.17	4.04	-3.1%
Senior	3.20	3.12	-2.7%

4.2 TOUR MODE CHOICE MODELS

To develop mode choice share targets for the tour mode choice models, the CHTS was used. Each of the tour mode models were calibrated by adjusting the alternative-specific constants for each mode to match the shares observed in the survey data. These calibrated coefficients are included in the model parameter tables in section 3. During calibration, it was noticed that the CHTS work transit and active mode shares were substantially higher in the MTC area than in the rest of the state; the "transit culture" of the Bay Area is a well-known phenomenon. To better represent this, a separate set of alternative-specific constants were developed for workers in the MTC area.

During validation, it was observed that – despite fitting the CHTS based targets – the model was producing substantially more transit trips than were reported "on the ground" by transit operators. This was felt to be the result of survey and respondent bias in favor of additional transit trips. Based on this transit operator data, the transit mode shares for grade school tours were adjusted down to 80% of the survey values, and the transit mode shares for other purpose tours were adjusted down to 50% of the survey values.

Figure 4.3 and 4.4 below shows the fit of the model versus the observed data, which is very good for all three tour mode models.

Figure 4.3 Work and School Tour Mode Model Calibration

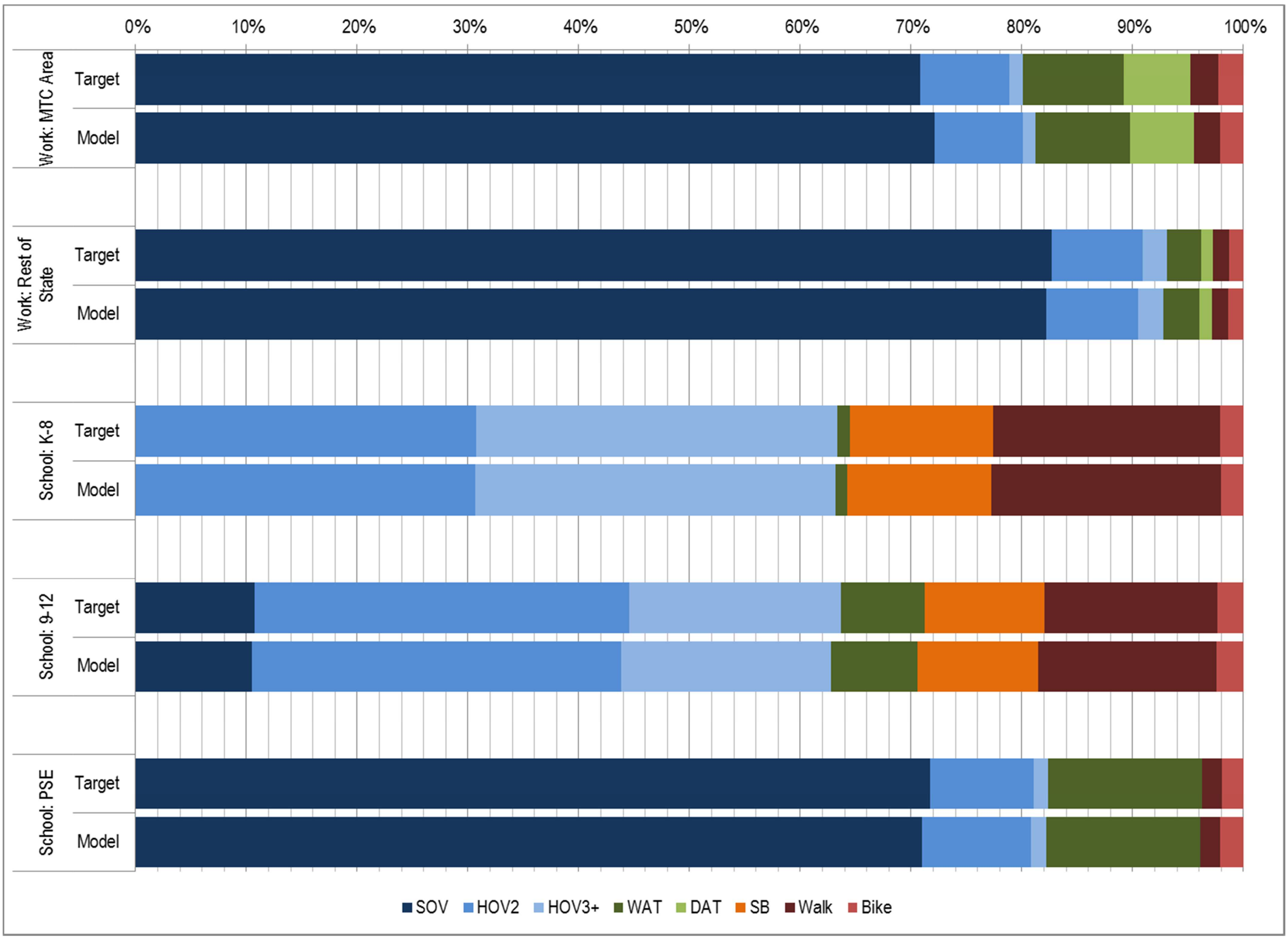


Figure 4.4 Other Tour Mode Model Calibration